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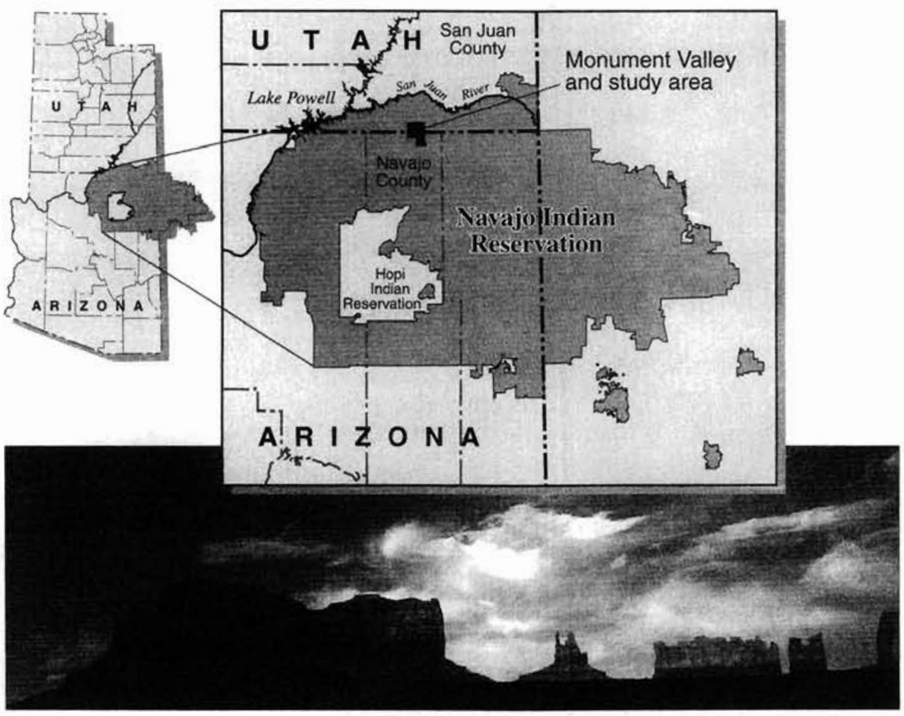
Prepared in cooperation with the
Navajo Nation Department of Water Resources

Hydrology and water quality of the Oljato alluvial aquifer, Monument Valley area, Utah and Arizona

By L.E. Spangler, U.S. Geological Survey; and
M.S. Johnson, Navajo Nation Department of Water Resources

WATER-RESOURCES INVESTIGATIONS REPORT 99–4074



U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

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INTRODUCTION

The Navajo Indian Reservation in Utah and Arizona is situated in one of the most arid parts of the Western United States. Normal annual precipitation is less than 8 to about 10 in. over much of the region (Cooley and others, 1969). Generally, water supplies for residents on the Reservation come from wells and springs, but locally, these supplies are small and, in some areas, they are slightly to moderately saline and not suitable for domestic purposes (Naftz and Spangler, 1994). One such area where water supply is limited is Monument Valley, along the Utah-Arizona State line, in the northern part of the Navajo Indian Reservation (fig. 1).

The main issue identified by the Navajo Nation Department of Water Resources (DWR) concerns adequate water supply for the residents of the Monument Valley area. Additional water sources need to be developed locally to avoid having water piped into the area and to minimize haulage of water for domestic use. In addition, supplemental water supplies need to be developed to meet the demands of an increasing number of tourists. Because of these needs, the Navajo Nation DWR, in cooperation with the U.S. Geological Survey, investigated the hydrology of, and quality of water in, an alluvial aquifer along a tributary of Oljato Wash, near Oljato, Utah (fig. 2).

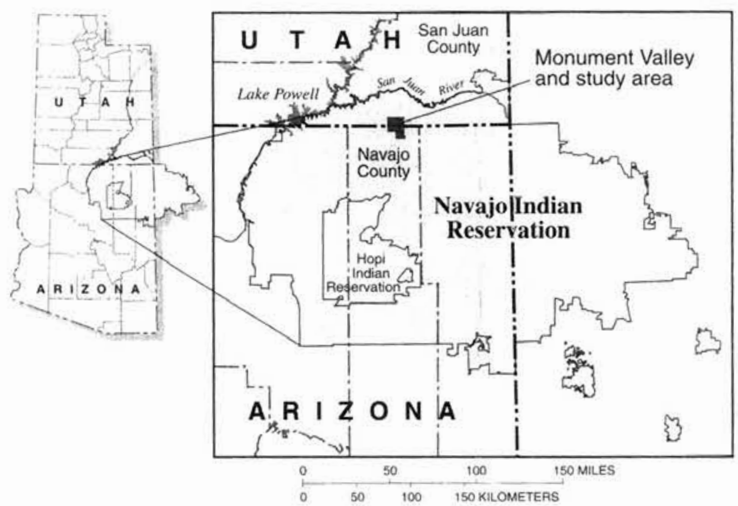


Figure 1. Location of Monument Valley and study area in San Juan County, Utah, and Navajo County, Arizona.

Previous Investigations

The last study to focus on water supply for the Navajo Nation that included the Monument Valley area began in 1950 and ended in the mid-1960s (Cooley and others, 1969). The principal objectives of that study were to inventory all wells and springs, investigate the geology and ground-water hydrology of sedimentary and igneous rocks in the area, and determine the feasibility of developing additional ground-water supplies. Geohydrologic data compiled during this investigation were published as a series of related reports by the Arizona State Land Department (Davis and others, 1963; Kister and Hatchett, 1963; Cooley and others, 1964; Cooley and others, 1966; and McGavock and others, 1966). A more specific investigation concerning geohydrology and water chemistry at abandoned uranium mines in the Monument Valley area was completed by Longsworth (1994).

Purpose and Scope

The purpose of this report is to describe (1) the composition and vertical and lateral extent of the alluvial deposits along an unnamed tributary of Oljato Wash, (2) the hydraulic characteristics of the aquifer contained within these deposits, (3) recharge to and discharge from the alluvial aquifer, and (4) the chemical quality of water in the aquifer.

Well records, water-use, water-quality, water-level, and aquifer-test data for this investigation were obtained from U.S. Geological Survey and Navajo Nation DWR data bases and from public water-supply system files. Aquifer data also were obtained from 15 monitoring wells drilled during the study, a multiple-well interference test completed in December 1996, single-well pumping tests for selected wells, and borehole-geophysical logs. Results of analysis of the multiple-well interference test were provided to the Navajo Nation DWR as a separate document (U.S. Geological Survey aquifer test, December 11-17, 1996). This report summarizes results of investigations done between October 1995 and October 1997.

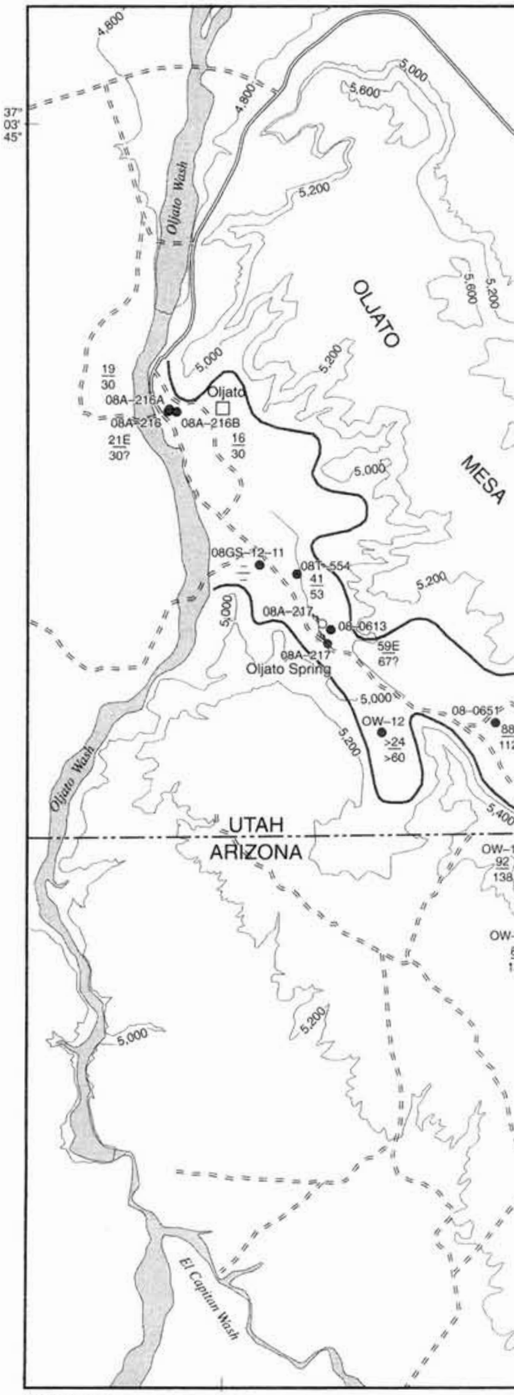
Acknowledgments

The authors acknowledge the assistance of all those who helped contribute to the completion of this study. The U.S. Geological Survey, Water Resources Division, Western Region drill crew was responsible for completion of most monitoring wells. Several wells also were completed by Bayles Exploration, Blanding, Utah, and Quality Drilling, Mexican Hat, Utah. Archaeological surveys were done by the Navajo Nation Archaeology Department, Farmington, New Mexico, to obtain clearance for drilling sites. Appreciation is extended to the staff members of the Oljato Chapter of the Navajo Nation for their valuable assistance with regard to permitting, clearances, and help during drilling activities. In addition, the authors greatly appreciate the assistance of the local public water-supply system managers in obtaining water samples and water levels and providing data for their wells.

Numbering System for Hydrologic-Data Sites

The local well-numbering system on the Navajo Indian Reservation is based on Bureau of Indian Affairs (BIA) administrative districts and numbered 15-minute quadrangles within each district. Well numbers consist of two basic parts. The first part is a number that designates the BIA district and a "K," "T," or another letter identifying the source of funds used in the drilling of the well; for wells drilled and inventories made before 1950, the first letter of the last name of the person who first inventoried the well or spring for the BIA is used. The letter "K" is used for wells drilled as part of the BIA drilling program, and the letter "T" is used for wells drilled as part of the Navajo Tribal Well Development Program. The second part of the BIA well number represents the order in which the drilled wells and the springs were inventoried in each district. Additional letters used at the end of some designations are obtained from the number of a nearby development that was inventoried previously. These letters are arranged consecutively beginning with "A."

In addition, monitoring wells drilled during this study are numbered consecutively in the order in which they were drilled, beginning with "OW-1" and ending with "OW-15," where "OW-3" indicates the third well drilled during the study. The location of all wells and springs inventoried also is expressed in latitude and longitude (degrees, minutes, seconds) and the corresponding Universal Transverse Mercator (UTM) coordinates (meters), and is presented in table 1.



Base from U.S. Geological Survey digital data, 1:100,000, 1981, and 1:24,000, 1987, 1988
Universal Transverse Mercator Projection
Zone 12

EXPLANATION

Approximate boundary of alluvial aquifer; d

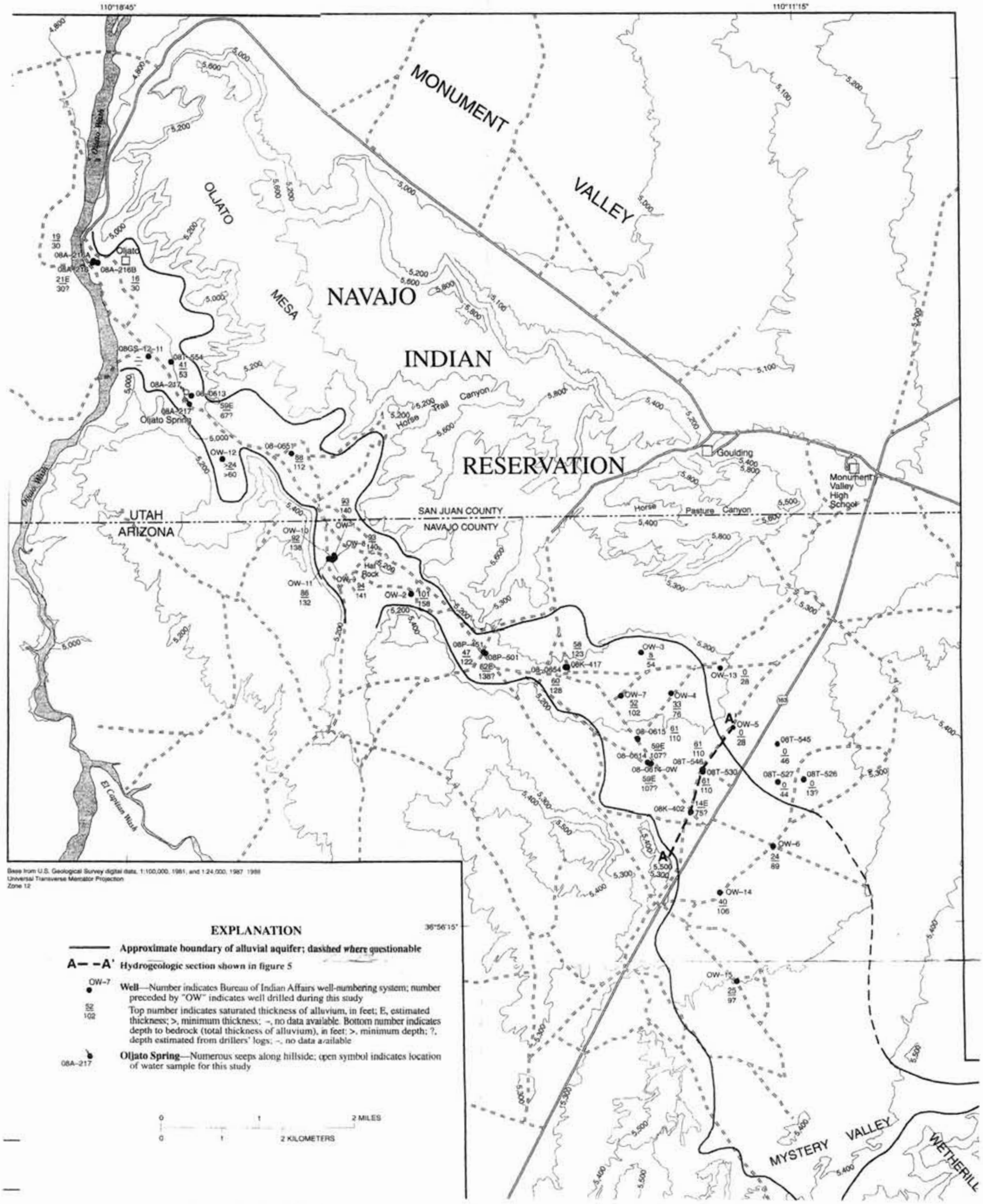


Figure 2. Location of selected wells and springs, th

Table 1. Records of selected wells and a spring in the Monument Valley area, Utah and Arizona

[deg, degrees; min, minutes; sec, seconds; Do., ditto; ND, no data; NA, not applicable; <, less than stated value; ?, data uncertain]

Map number: Refer to numbering system for hydrologic-data sites; locations shown in figure 2.
UTM: Universal Transverse Mercator.
Altitude of land surface: In feet above sea level.
Perforated/screened/open interval: In feet below land surface.
Static water level: In feet below land surface; R, reported value.
Well yield: gal/min, gallons per minute.
Use of water: U, unused; P, public supply; S, stock.
Available information: D, driller's log; QW, water-quality data; L, lithologic log; G, geophysical log; P, aquifer/pumping-test data.

Map number	Latitude (deg/min/sec)	Longitude (deg/min/sec)	UTM coordinates, easting (meters)	UTM coordinates, northing (meters)	Altitude of land surface (feet)	Owner/ Operator	Date of well completion	Depth of well (feet)	Perforated/ screened/ open interval	Static water level (feet)	Date water level measured	Well yield (gal/ min)	Use of water	Available information	Remarks
OW-1	365933	1101625	564651	4094097	5,096.48	Navajo Nation	07-17-96	158	100-140	47.09	09-23-97	ND	U	D,QW,L,G,P	Observation well
OW-2	365913	1101531	565985	4093483	5,137.85	Do.	07-17-96	177	118-158	56.72	09-23-97	<10	U	D,QW,L,G,P	Monitoring well
OW-3	365840	1101259	569737	4092505	5,192.84	Do.	07-17-96	55	20-54	45.91	09-23-97	ND	U	D,QW,L,G,P	Do.
OW-4	365818	1101240	570224	4091830	5,197.55	Do.	07-19-96	74	39-74	43.33	09-23-97	11	U	D,QW,L,G,P	Do.
OW-5	365800	1101159	571233	4091275	5,211.20	Do.	07-19-96	59	30-59	38.79	09-23-97	<1	U	D,QW,L,G	Completed in Organ Rock Tongue
OW-6	365656	1101134	571880	4089318	5,254.64	Do.	07-21-96	88	60-88	65.12	08-25-97	ND	U	D,QW,L,G	Monitoring well
OW-7	365817	1101313	569403	4091792	5,193.01	Do.	07-23-96	104	56-96	49.55	09-23-97	11	U	D,QW,L,G,P	Do.
OW-8	365933	1101625	564645	4094084	5,096.30	Do.	07-24-96	142	72-135	46.77	09-23-97	130	U	D,QW,L,G,P	Aquifer test well
OW-9	365933	1101625	564638	4094070	5,096.20	Do.	08-01-96	170	148-168	46.61	09-23-97	8	U	D,L,G,P	Completed in DeChelly Sandstone
OW-10	365933	1101626	564614	4094080	5,095.55	Do.	08-01-96	138	98-138	46.00	09-23-97	ND	U	D,L,G,P	Observation well
OW-11	365933	1101628	564554	4094071	5,095.32	Do.	08-01-96	129	89-129	45.64	09-23-97	ND	U	D,L.G,P	Do.
OW-12	370026	1101738	562822	4095710	5,030	Stanley Holiday	08-22-96	50	40-50	36.07	09-23-97	ND	U	D,L	Monitoring well
OW-13	365832	1101207	571025	4092246	5,200.62	Navajo Nation	08-25-97	50	NA	NA	NA	NA	NA	L	Plugged and abandoned
OW-14	365632	1101209	571004	4088568	5,266.62	Do.	08-27-97	107	75-105	66.33	09-23-97	10	U	D,QW,L,G,P	Monitoring well
OW-15	365545	1101159	571272	4087097	5,297.25	Do.	08-28-97	105	63-103	71.82	09-23-97	<5	U	D,QW,L,G,P	Do.
08A-216	370211	1101903	560690	4098930	4,838	Oljato Trading Post	10-48?	18	18	4 R 9.05	10-01-48 05-21-98	ND	U	D,QW	Abandoned windmill
08A-216A	370212	1101903	560700	4098950	4,840	Oljato Trading Post	07-51	100	31-100?	11 R 10.74	07-07-51 01-23-98	30	U	D,QW,L	Deepened to 130 feet in 1954?
08A-216B	370211	1101900	560773	4098924	4,840	Navajo Tribal Utility Authority	10-53	50	32-50?	12 R 14.0 R	10-29-54 08-02-90	30	P	QW,L,P	Public water supply
08A-217	370056	1101760	562275	4096620	4,960	Navajo Nation	NA	NA	NA	0	NA	20	S	QW	Oljato Spring
08K-402	365715	1101228	570540	4089890	5,245	Do.	03-14-39	123	113-123	55 R 66.9 R 60.46	03-14-39 08-11-49 05-28-98	<2	S	QW,L	Windmill; plumbed to 76.5 feet 5/98
08K-417	365833	1101348	568529	4092267	5,190	RGJ, Incorporated	06-47	137	ND	64.8 R	06-08-48	60-80	P	QW,L,P	Gouldings well
08P-451	365841	1101443	567170	4092516	5,180	Seventh Day Adventist Church	06-60	130	82-122	75.34	05-27-98	50	P	QW,L,P	Hospital/Mission well
08P-501	365841	1101442	567198	4092501	5,180	Do.	1967?	138	ND	75.84	05-27-98	12	P	L	Do.
08T-526	365732	1101113	572384	4090418	5,230	Navajo Nation	07-19-68	25	25	NA	NA	NA	U	L	Plugged and abandoned
08T-527	365731	1101130	571964	4090383	5,230	Do.	07-18-68	68	68	NA	NA	NA	U	L	Do.
08T-530	365737	1101220	570733	4090569	5,220	Parks and Recre-ation Department	12-75?	113	ND	49 R 48.85	12-24-75 05-28-98	ND	U	P	Movie Company well
08T-545	365751	1101130	571950	4091005	5,225	Navajo Nation	01-12-78	300	300?	60 R	01-12-78	<.5	U	L	Plugged and abandoned
08T-546	365738	1101220	570733	4090588	5,220	Parks and Recre-ation Department	03-01-78	120	80-110	49 R 50 R	03-01-78 04-29-97	42	P	QW,L,P	Tribal Park well
08T-554	370118	1101812	561971	4097300	4,920	Navajo Tribal Utility Authority	08-83	62	45-55	11.91 R	09-01-83	30	P	QW,L,P	Public water supply

UW-7 **Well**—Number indicates Bureau of Indian Affairs well-numbering system; number preceded by "OW" indicates well drilled during this study

52/102 Top number indicates saturated thickness of alluvium, in feet; E, estimated thickness; >, minimum thickness; –, no data available. Bottom number indicates depth to bedrock (total thickness of alluvium), in feet; >, minimum depth; ?, depth estimated from drillers' logs; –, no data available

08A–217 **Oljato Spring**—Numerous seeps along hillside; open symbol indicates location of water sample for this study

0 1 2 MILES

0 1 2 KILOMETERS

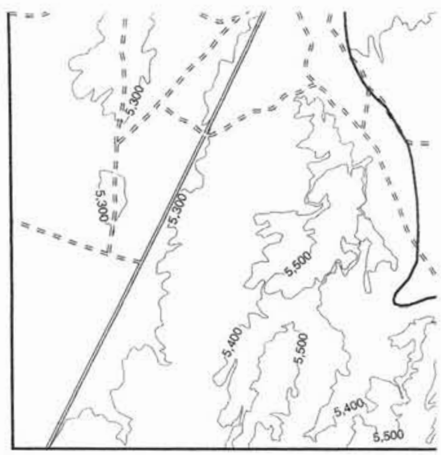


Figure 2. Location of selected wells and springs, thickness of the Oljato alluvial aquifer, and depth to bedrock, Monument Valley area, Utah and Arizona.

k Tongue

Sandstone

1954?

5 feet 5/98

Description of Study Area

The study area lies within the Monument Valley region and straddles the boundary between the States of Arizona and Utah, near the communities of Oljato and Goulding, Utah (figs. 1 and 2). The study area is within the Oljato Chapter of the Navajo Nation and includes about 15 mi^2 along an unnamed, northwest-trending tributary valley that joins Oljato Wash near Oljato, Utah (fig. 2). The area is within the Colorado Plateau physiographic province and is characterized by mesas and buttes with intervening canyons and broad valleys. Land-surface altitude in the area ranges from about 4,800 ft above sea level along Oljato Wash to as much as 6,100 ft on Wetherill Mesa (fig. 2).

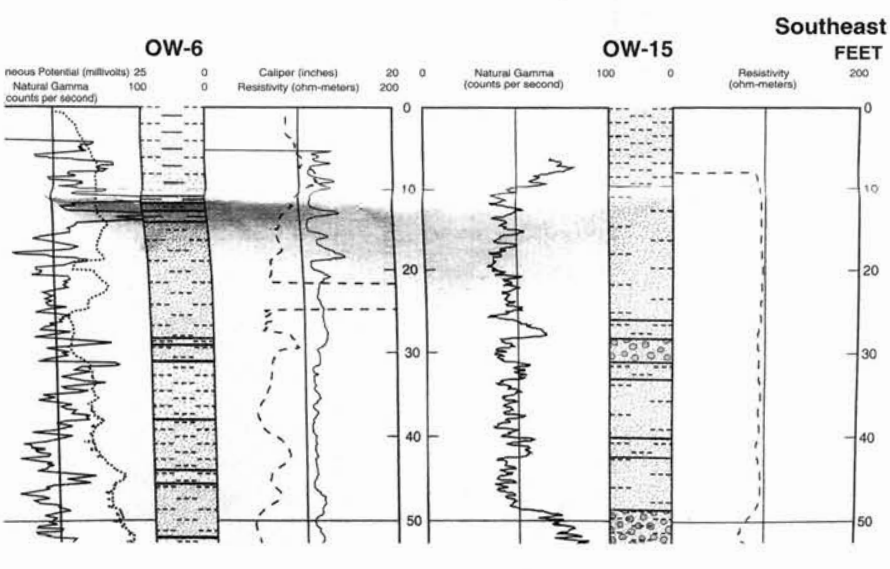
Many of the tributaries to Oljato Wash, a north-trending drainage to the San Juan River, are ephemeral, and surface-water flow in parts of Oljato Wash also is ephemeral. Surface drainage in much of the study area is poorly developed and integrated, particularly in the southeastern part of the valley where the landscape consists of stabilized dunes. Few perennial streams are present in the study area and surface flow generally occurs only after intense thunderstorms.

Annual precipitation in the study area averages about 8 in. (Cooley and others, 1969). Much of this precipitation comes from thunderstorms in late summer that provide 50 to 65 percent of the annual total (McDonald, 1956, fig. 7). Because the climate is arid, potential annual evaporation is much greater than precipitation. Daytime summer temperatures in the study area typically exceed 35°C. Vegetation is sparse, consisting of a desert scrub community in the valley and pinon-juniper on adjacent mesa tops (Cooley and others, 1969).

Geology

Unconsolidated alluvial deposits of Quaternary age are present along Oljato Wash and its tributaries (Cooley and others, 1969). In the study area, these deposits consist of interbedded clay, silt, sand, and gravel (fig. 3). The DeChelly Sandstone Member and Organ Rock Tongue of the Permian-age Cutler Formation underlie the alluvium in the northwestern part of the valley (Baker, 1936; Irwin and others, 1971). The Organ Rock Tongue is composed of interbedded mudstone, siltstone, and sandstone. In the southeastern part of the valley, the base of the DeChelly Sandstone is above land surface because rocks dip to the west, or has been removed by erosion, and the alluvium is directly underlain by the Organ Rock Tongue. On the basis of drillers' logs, this subsurface transition is present in the vicinity of well 08K-417 (fig. 2).

A profile from northwest to southeast across the study area (up valley) constructed using data from selected wells drilled through the alluvium to bedrock (fig. 3) shows



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Variations in thickness of
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HYDROLOGY OF THE

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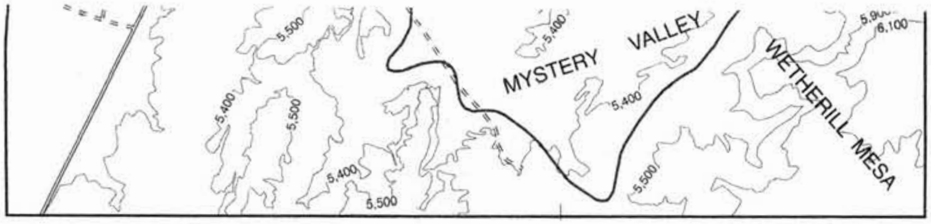

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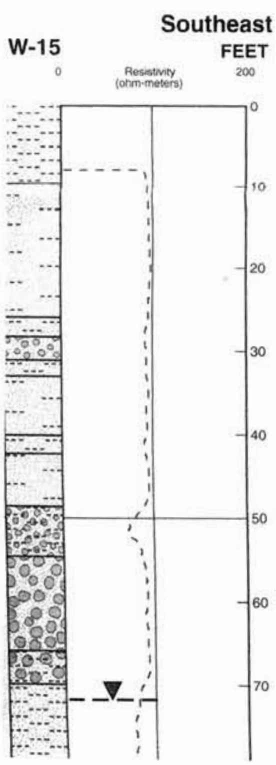


that the upper part of the alluvium is generally finer grained than the lower part, which is predominantly sand and gravel. These sands and gravels provide the largest amount of water to wells. Natural gamma geophysical log responses also reflect the complex interbedding of fine and coarse materials within the alluvium that is not discernible using only lithologic descriptions based on drill cuttings (fig. 3). Because variations in lithologic character of these deposits are substantial throughout the study area, only generalized correlation of strata between wells can be done.

Variations in thickness of alluvial deposits (depth to bedrock) in the study area are shown in figures 2 and 3. Maximum known thickness of alluvium is 158 ft in well OW-2 near Hat Rock (fig. 2). Thickness of alluvium gradually decreases down valley toward Oljato, averaging only 30 to 60 ft. Up valley from Hat Rock, thickness of alluvium also decreases, and the maximum measured thickness is about 106 ft near Mystery Valley. Thicker alluvial deposits in the Hat Rock area could have resulted from input of fluvial sediments from areas to the south (fig. 2). Lithologic data from drillers' logs, in conjunction with well locations, indicate that the thickest alluvium probably is associated with one or more paleochannels. These buried channels, however, are not necessarily coincident with the present surface drainage.

HYDROLOGY OF THE ALLUVIAL AQUIFER

The principal aquifer in the study area is contained within the unconsolidated alluvial deposits that overlie the bedrock units throughout the valley. This aquifer herein is referred to as the "Oljato alluvial aquifer" to differentiate this aquifer from alluvial aquifers that are present along Oljato Wash and other tributaries. The alluvial deposits are unsaturated to partly saturated, except in downgradient areas near Oljato Wash, where the water table locally intersects the land surface. Several of the public-supply wells that yield water from the alluvium also are open to the upper part of the DeChelly Sandstone. Although these units are connected hydraulically, hydraulic conductivity of the DeChelly Sandstone is small compared with that of the overlying alluvium, and well yields from this unit generally are low (table 1).

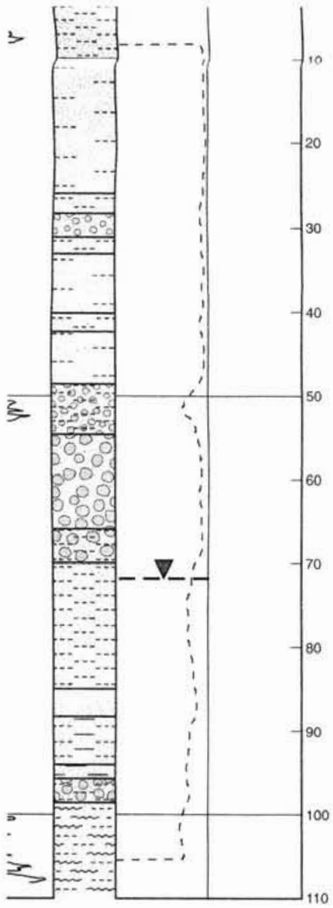
Areal Extent, Thickness, and Hydraulic Properties

The Oljato alluvial aquifer is bounded physically by outcrops of the DeChelly Sandstone and Organ Rock Tongue along much of the valley. The alluvium also is not saturated in areas where these deposits are not thick enough to intercept the regional water table. The approximate areal extent of the alluvial aquifer as determined from well logs, water levels, and geology is about 9,500 acres (figs. 2 and 4). Downgradient, the aquifer merges with saturated alluvial deposits in Oljato Wash and likely thins to zero in upgradient areas (Mystery Valley), where the alluvium is presumed to pinch out against the bedrock boundaries of adjacent mesas and buttes (fig. 2).

Thickness of the alluvial aquifer is shown in figure 2. On the basis of measured water levels in 1996-97 and depth to bedrock, maximum thickness of the aquifer is 101 ft at well OW-2 near Hat Rock. Thickness of the aquifer decreases both downgradient and upgradient from this area (fig. 2). Thickness of the aquifer at well 08A-216B in Oljato is only 16 ft but averages about 58 ft in upgradient areas where most of the water-supply wells are located. At well OW-15 in the Mystery Valley area, thickness of the aquifer decreases to about 25 ft, although total thickness of the alluvium is almost 100 ft (fig. 3). Thickness of the aquifer also decreases rapidly toward valley margins in much of the area. Thickness of the aquifer at well OW-3, about 1,300 ft from the valley bedrock wall, is only about 8 ft (fig. 2).

A hydrogeologic section that includes wells 08K-402, 08T-546, and OW-5 (figs. 2 and 5) shows that, from well 08T-546, alluvial and aquifer thickness decrease rapidly to the northeast across the valley and toward the southwest. Thickness of alluvium at well 08T-546 (the Tribal Park well) is about 110 ft, of which about 61 ft is saturated. Thickness of the alluvium at well 08K-402, about 3,000 ft to the south, is about 75 ft, of which only about 14 ft is saturated. About 3,000 ft northeast of well 08T-546, the alluvium decreases in thickness to only about 28 ft at well OW-5 and is not saturated because regional water levels are below the base of the alluvium and in the underlying bedrock unit (figs. 4 and 5). The alluvium also is unsaturated in areas north, east, and southeast of well OW-5 (fig. 2). Most public-supply wells in this part of the study area, such as well 08T-546, appear to be aligned along a southeast-trending paleochannel(s) where aquifer thickness is greatest. Thus, an understanding of the hydrogeologic framework is important for successfully obtaining adequate water supplies in this area.

Transmissivity values reported and determined for selected wells in the Oljato alluvial aquifer range from less than 100 to as much as 2,800 ft2/d (table 2). Variations



is 101 ft at well OW-2 near Hat Rock. Thickness of the aquifer decreases both downgradient and upgradient from this area (fig. 2). Thickness of the aquifer at well 08A-216B in Oljato is only 16 ft but averages about 58 ft in upgradient areas where most of the water-supply wells are located. At well OW-15 in the Mystery Valley area, thickness of the aquifer decreases to about 25 ft, although total thickness of the alluvium is almost 100 ft (fig. 3). Thickness of the aquifer also decreases rapidly toward valley margins in much of the area. Thickness of the aquifer at well OW-3, about 1,300 ft from the valley bedrock wall, is only about 8 ft (fig. 2).

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Transmissivity values reported and determined for selected wells in the Oljato alluvial aquifer range from less than 100 to as much as 2,800 ft^2/d (table 2). Variations in transmissivity result from differences in aquifer thickness, hydraulic conductivity, and lithologic character of the alluvial deposits. Where aquifer thickness is large and alluvial deposits consist of predominantly coarse materials, transmissivity values can be high and well yields potentially large. Transmissivity determined from a multiple-well interference test near Hat Rock averages 1,250 ft^2/d (table 2). Given a saturated thickness of 93 ft at this test site, hydraulic conductivity of the aquifer would be 13.4 ft/d. On the basis of this test (U.S. Geological Survey aquifer test, December 11-17, 1996), potential well yield in this area is at least 130 gal/min. Reported transmissivity of the aquifer in the vicinity of well 08T-554 averages 300 ft^2/d (table 2). Although aquifer thickness at well OW-14 in the upgradient part of the study area is the same as that at well 08T-554 (fig. 2), results of analysis of a single-well test indicate a transmissivity of 70 to 100 ft^2/d (table 2). Differences in transmissivity between these areas probably reflect differences in hydraulic conductivity of the alluvial deposits.

Specific-capacity values determined for selected wells also indicate that transmissivity of the alluvial aquifer varies substantially throughout the study area. Specific capacity ranges from 0.6 to 5.8 (gal/min)/ft of drawdown (table 2); larger values generally correspond with areas of high transmissivity. Specific capacity for well 08-0614 is 0.6 and transmissivity estimated from specific capacity is about 120 ft^2/d (table 2). Specific capacity determined for well 08-0615 only 1,300 ft to the northwest, however, is 4.4 and transmissivity estimated from specific capacity is 940 to 1,100 ft^2/d (table 2). Although thickness of the aquifer is about the same in both wells 08-0614 and 08-0615 (fig. 2), well yields are 17 and 84 gal/min, respectively (table 1).

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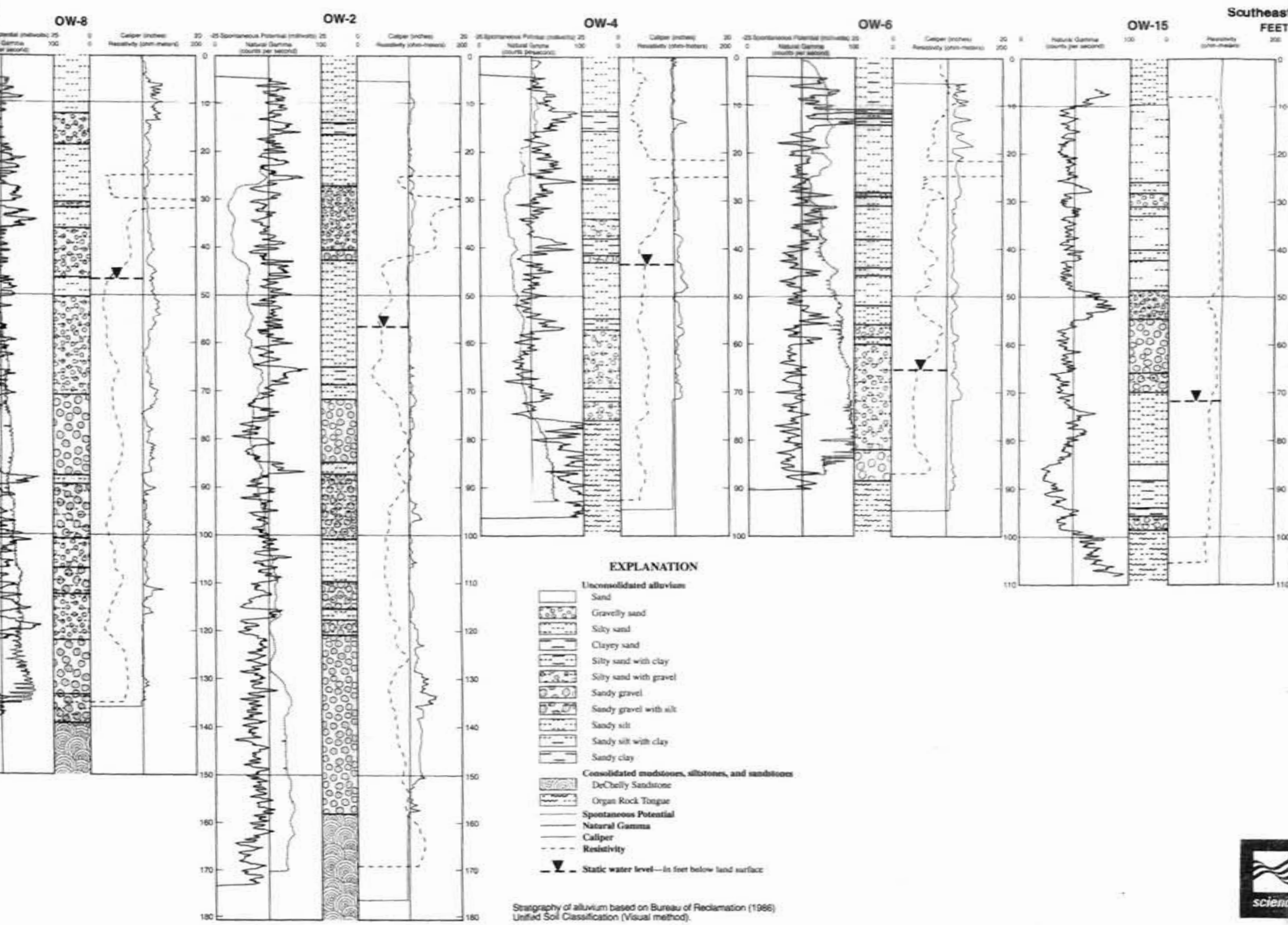

iagrams showing correlation of natural gamma, spontaneous potential, resistivity, and caliper logs to stratigraphy for selected monitoring wells in the Oljato alluvial aquifer, Monument Valley area, Utah and Arizona.

is presumed to pinch out against the bedrock boundaries of adjacent mesas anc buttes (fig. 2).

Thickness of the alluvial aquifer is shown in figure 2. On the basis of meas water levels in 1996-97 and depth to bedrock, maximum thickness of the aquif is 101 ft at well OW-2 near Hat Rock. Thickness of the aquifer decreases both downgradient and upgradient from this area (fig. 2). Thickness of the aquifer at 08A-216B in Oljato is only 16 ft but averages about 58 ft in upgradient areas w most of the water-supply wells are located. At well OW-15 in the Mystery Vall area, thickness of the aquifer decreases to about 25 ft, although total thickness the alluvium is almost 100 ft (fig. 3). Thickness of the aquifer also decreases ra toward valley margins in much of the area. Thickness of the aquifer at well O about 1,300 ft from the valley bedrock wall, is only about 8 ft (fig. 2).

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Hydrology and water quality of the Oljato alluvial aquifer, Monument Valley area, Utah and Arizona

By

L.E. Spangler, U.S. Geological Survey; and M.S. Johnson, Navajo Nation Department of Water Resources

1999

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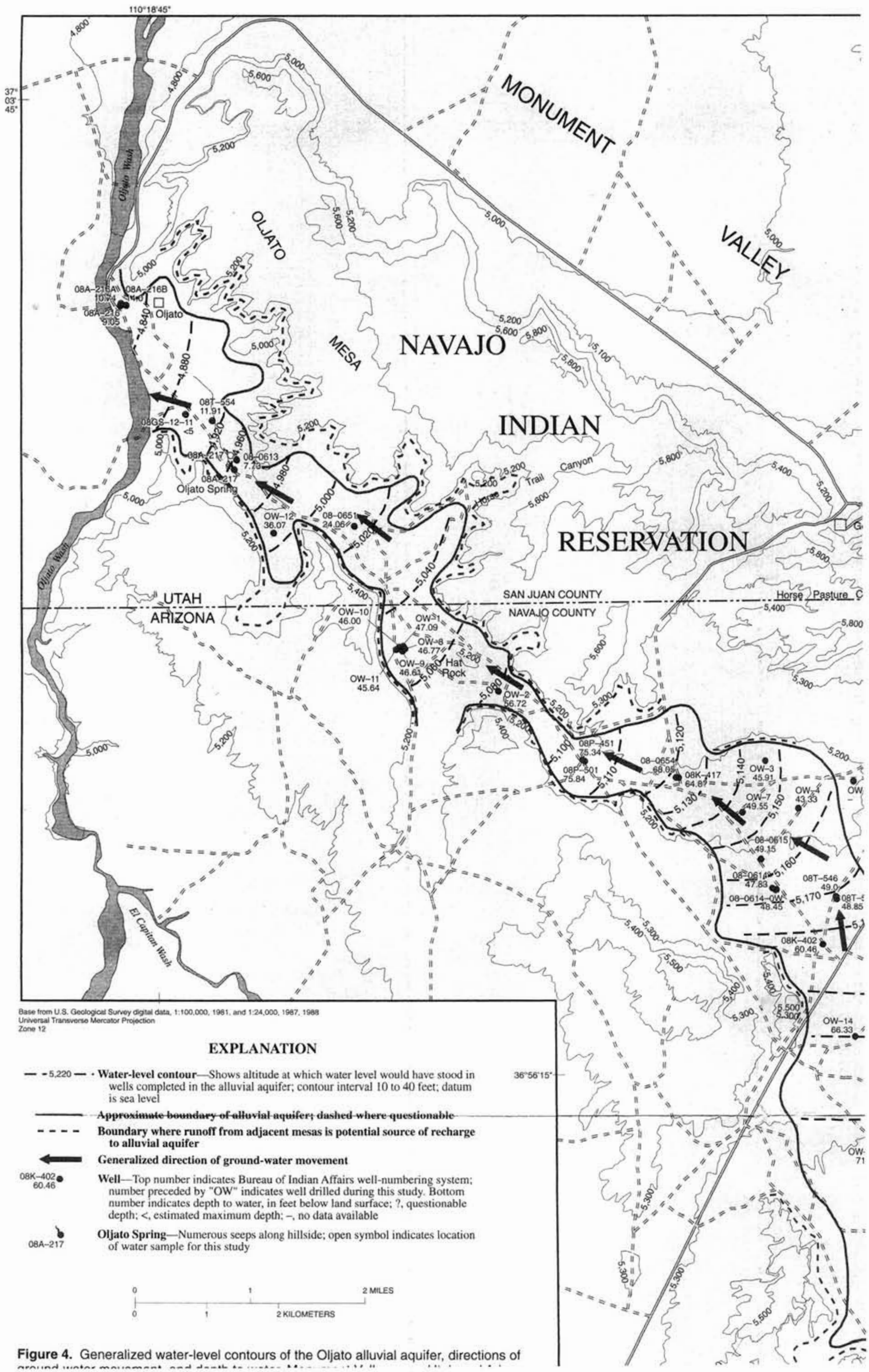


EXPLANATION

— - 5,220 — · **Water-level contour**—Shows altitude at which water level would have stood in wells completed in the alluvial aquifer; contour interval 10 to 40 feet; datum is sea level

~~**Approximate boundary of alluvial aquifer; dashed where questionable**~~

Boundary where runoff from adjacent mesas is potential source of recharge to alluvial aquifer

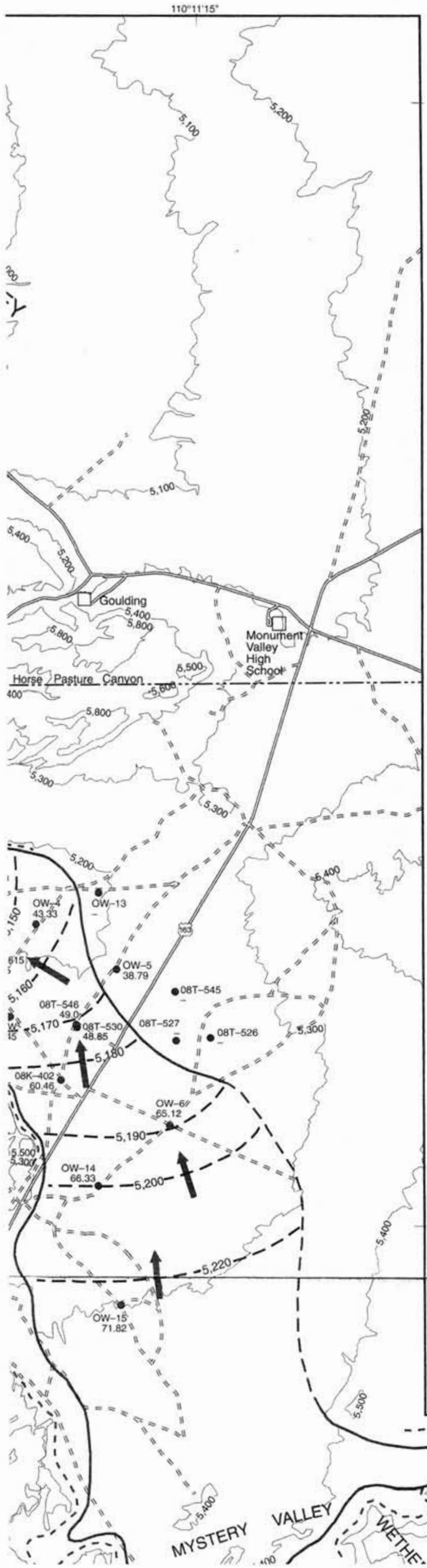
Generalized direction of ground-water movement

08K-402 60.46 **Well**—Top number indicates Bureau of Indian Affairs well-numbering system; number preceded by "OW" indicates well drilled during this study. Bottom number indicates depth to water, in feet below land surface; ?, questionable depth; <, estimated maximum depth; –, no data available

08A-217 **Oljato Spring**—Numerous seeps along hillside; open symbol indicates location of water sample for this study

0 1 2 MILES
0 1 2 KILOMETERS

Figure 4. Generalized water-level contours of the Oljato alluvial aquifer, directions of



Total direct precipitation on the alluvium in the study area is approxim acre-ft/yr, based on an average precipitation rate of 8 in/yr over an areal about 9,500 acres. Given a conservative transmissivity value of about 30 determined from pumping tests for water-supply wells 08-0613 and 08T- 2); a hydraulic gradient of about 0.025 ft/ft in the area of these wells; and cross-sectional area of about 100,000 ft^2, based on an average aquifer thi 40 ft in the vicinity of these wells; then potential ground-water discharge alluvial aquifer to Oljato Wash (underflow) is estimated to be about 160 On the basis of these assumptions and known withdrawals from the aqui pumpage, potential recharge to the alluvial aquifer is estimated to be abou (0.4 in.) of the precipitation that falls directly on this area, or about 300 Because an additional unknown amount of recharge to the aquifer originate from adjacent mesas, recharge to the alluvial aquifer as a percentage of pr could be less.

Water Use

Water from the alluvial aquifer is used for municipal, domestic, comn irrigation, and stock purposes. Monument Valley Tribal Park, Gouldings Post and Lodge, Monument Valley High School, Monument Valley Hospit and the community of Oljato use this aquifer as their primary source of c water (table 3). On the basis of water-use records from January 1992 to J the average total amount of water withdrawn by these systems was about gal/month (133 acre-ft/yr). Monument Valley High School and Goulding Post and Lodge are the principal users of water in the study area, averagi three-fourths of the total amount of water withdrawn from the aquifer du period. Some ground water in the study area also is withdrawn by windn 402) and dug wells (08GS-12-11) or is supplied naturally by springs (08A used mostly for livestock watering. The amount of use from these sources i and not monitored but is considered small in comparison with that utilized water supply.

Table 3. Average water use from the Oljato alluvial aquifer by public-water syste Monument Valley area, Utah and Arizona

System	Operator	Water-source wells	Average use (gallons per month)	Annual use (acre-feet per year)	P
Monument Valley Tribal Park	Parks and Recreation Department	08T-546	31,376	1.2	01–
Monument Valley High School	San Juan County School District	08-0614 08-0615	1,479,176	54.5	04–
Monument Valley Hospital/Mission	Seventh Day Adventist Church	08P-451 08P-501	216,787	8.0	08–
Oljato community	Navajo Tribal Utility Authority (NTUA)	08A-216B 08T-554	718,303	26.4	01–
Goulding Trading Post and Lodge	RGJ, Incorporated	08K-417	1,166,477	43.0	07–

Because water use for Monument Valley Tribal Park and Gouldings Tra and Lodge is mostly for tourism, water demand is seasonal. Greater amou water are used during the summer than are used during the winter. Monthl use for the Tribal Park during March 1996 was about 3,000 gal and during 1998, was 98,750 gal. Monthly water use for the Gouldings Trading Post a for August 1994 was about 2,180,000 gal and for February 1995, was about gal. Water use for Monument Valley High School also varies seasonally. D summer when school is not in session, less water is used for domestic purp use for irrigation (lawn watering) is greater.

The total volume of water in storage in the alluvial aquifer and the volu water actually available for use cannot be determined accurately because c heterogeneity and large variations in thickness. If average saturated thickne 30 ft and specific yield (percentage of the aquifer that is potentially drain about 20 percent for sand and gravel (Heath, 1989, p. 9), a volume of abo acre-ft potentially would be available for withdrawal from the aquifer. At recharge rate of 300 acre-ft, as previously calculated, about 200 years wo required to replenish this loss from storage.

CHEMICAL QUALITY OF GROUND WATER

Water samples from 18 wells and 1 spring were collected during and analyzed for major ions, selected trace metals, alkalinity, and solids concentration to assess variations in water quality in the Olja aquifer (table 4). Water-quality data for three additional sites (wells 08A-216A, and 08-0613) also are reported. Temperature, pH, and n the study area is approximately 6,300 rate of 8 in/yr over an areal extent of ;missivity value of about 300 ft^2/d,)ply wells 08-0613 and 08T-554 (table ı the area of these wells; and an aquifer ;ed on an average aquifer thickness of ıtial ground-water discharge from the s estimated to be about 160 acre-ft/yr. ı withdrawals from the aquifer by ıuifer is estimated to be about 5 percent / on this area, or about 300 acre-ft/yr. :harge to the aquifer originates as runoff aquifer as a percentage of precipitation

r municipal, domestic, commercial, ılley Tribal Park, Gouldings Trading ›ol, Monument Valley Hospital/Mission, · as their primary source of drinking :ords from January 1992 to June 1998, by these systems was about 3,600,000 / High School and Gouldings Trading ter in the study area, averaging almost thdrawn from the aquifer during this also is withdrawn by windmills (08K-ied naturally by springs (08A-217) and nt of use from these sources is unknown :omparison with that utilized for public-

/ial aquifer by public-water systems,

Average use (gallons per month)	Annual use (acre-feet per year)	Period of record
31,376	1.2	01–92 to 01–96
1,479,176	54.5	04–92 to 04-98
216,787	8.0	08–92 to 10–95
718,303	26.4	01–92 to 01–98
1,166,477	43.0	07–93 to 06–98

Tribal Park and Gouldings Trading Post ınd is seasonal. Greater amounts of ısed during the winter. Monthly water /as about 3,000 gal and during August the Gouldings Trading Post and Lodge l for February 1995, was about 580,000 :hool also varies seasonally. During the vater is used for domestic purposes, but

ıe alluvial aquifer and the volume of termined accurately because of aquifer ;s. If average saturated thickness is only ıuifer that is potentially drainable) is , 1989, p. 9), a volume of about 57,000 hdrawal from the aquifer. At an annual ılculated, about 200 years would be

OUND WATER

spring were collected during this study trace metals, alkalinity, and dissolved-ns in water quality in the Oljato alluvial)r three additional sites (wells 08A-216,)orted. Temperature, pH, and specific :ld at most sites. Water-quality samples :ted after wells had been pumping for :s from monitoring wells drilled during

Oljato Wash. Because well spacing in the study area is typically greater than 3,000 ft and public-supply wells are pumped intermittently at low rates, effects of pumpage on neighboring wells probably do not occur.

Recharge to the Oljato alluvial aquifer originates primarily from direct precipitation in the valley and from infiltrating streamflow that originates as runoff from mesas immediately adjacent to the valley. The greatest potential for areal recharge to the alluvial aquifer is during the winter. Discharge from the alluvial aquifer is from ground-water pumpage, springs, and underflow to Oljato Wash. Total direct precipitation on the alluvium in the study area is approximately 6,300 acre-ft/yr. Given an average precipitation rate of 8 in/yr, potential recharge to the alluvial aquifer is estimated to be about 300 acre-ft/yr. Potential ground-water discharge from the alluvial aquifer to Oljato Wash is estimated to be about 160 acre-ft/yr.

Water from the alluvial aquifer is used for municipal, domestic, commercial, irrigation, and stock purposes. The average total amount of water withdrawn by eight public supply wells is about 133 acre-ft/yr. If the average saturated thickness is 30 ft and specific yield is about 20 percent, about 57,000 acre-ft potentially would be available for withdrawal from the aquifer.

Dissolved-solids concentration in water from the Oljato alluvial aquifer ranged from 179 to 789 mg/L, and water from most wells contained less than 300 mg/L. Water from most wells is a calcium-magnesium-bicarbonate type and would be considered "hard." Water from wells in the community of Oljato contains the highest dissolved-solids concentrations in the study area that result from increased concentrations of sodium and sulfate. Better quality water in downgradient areas possibly could be obtained by well completion in the underlying bedrock.

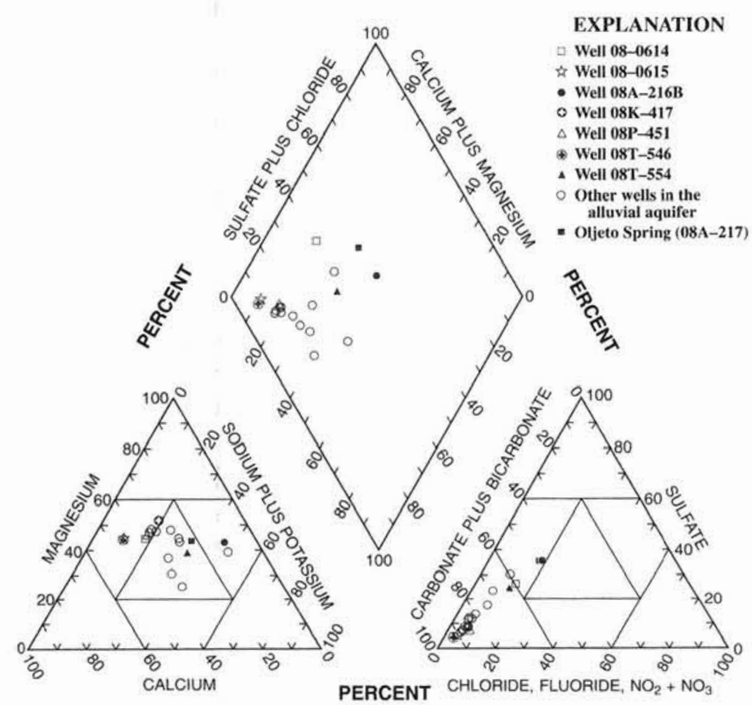


Figure 7. Quality of water in the Oljato alluvial aquifer, Monument Valley area, Utah and Arizona.

REFERENCES CITED

Baker, A.A., 1936, Geology of the Monument Valley-Navajo Mountain region, San Juan County, Utah: U.S. Geological Survey Bulletin 865, 106 p.

Cooley, M.E., Akers, J.P., and Stevens, P. R., 1964, Geohydrologic data in the Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah; Part III—Selected lithologic logs, drillers' logs, and stratigraphic sections: Arizona State Land Department Water-Resources Report Number Twelve-C, 157 p.

Cooley, M.E., and others, 1966, Geohydrologic data in the Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah; Part III—Maps showing locations of wells, springs, and stratigraphic sections: Arizona State Land Department Water-Resources Report Number Twelve-D, 2 sheets.

Cooley, M.E., Harshbarger, J.W., Akers, J.P., and Hardt, W.R., 1969, Regional hydrogeology of the Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah, with a section on Vegetation, by O.N. Hicks: U.S. Geological Survey Professional Paper 521-A, 61 p.

Davis, G.E., Hardt, W.F., Thompson, L.K., and Cooley, M.E., 1963, Geohydrologic data in

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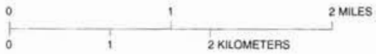


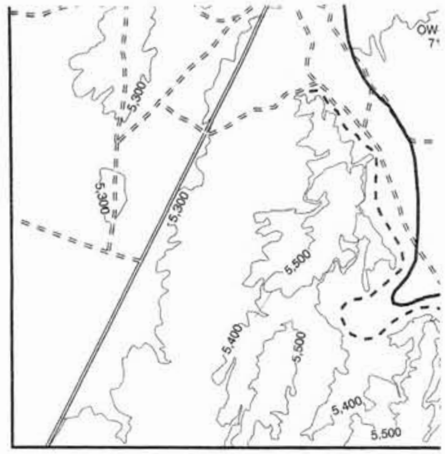


Figure 4. Generalized water-level contours of the Oljato alluvial aquifer, directions of ground-water movement, and depth to water, Monument Valley area, Utah and Arizona.

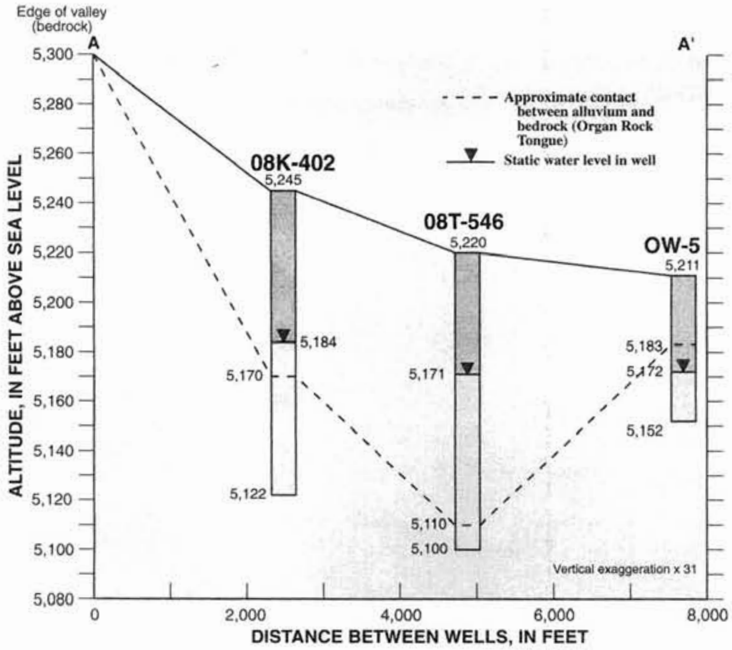


Figure 5. Hydrogeologic section from edge of valley to well OW-5, showing altitude of contact between alluvium and bedrock and thickness of the alluvial aquifer, Monument Valley area, Utah and Arizona. (Trace of section shown in figure 2.)

Water Levels and Ground-Water Movement

Ground-water availability and movement in the Oljato alluvial aquifer are influenced largely by the lithologic character and hydraulic properties of the alluvial deposits. Water levels measured in selected wells were used to determine directions of ground-water movement in the alluvial aquifer (fig. 4). Differences in water levels are attributed partially to differences in well depth and length of perforated or open interval in wells. Water levels in some wells can be influenced by vertical hydraulic gradients within the aquifer that result from semiconfining layers within the alluvium. In addition, water levels measured in some wells also can be influenced by inflow of water from underlying bedrock units where both the alluvium and bedrock are open to the well and head differences exist between the units.

Monthly measurements of water levels from August 1996 to September 1997 in five wells are shown in figure 6. Water levels in most wells varied only 0.2 ft or less during this period. Daily water-level measurements in well OW-2 for the month prior to an aquifer test in December 1996 also show variations of less than 0.04 ft, even during changes in barometric pressure (U.S. Geological Survey aquifer test, December 11-17, 1996). Water levels measured in some wells during this study were virtually the same as water levels measured when the wells were drilled (table 1). Long-term water-level data for the alluvial aquifer do not exist and would be necessary to document variability caused by seasonal effects and potential water-level declines from pumpage.

Depth to water in the study area generally decreases downgradient as land-surface altitude also decreases. Measured depth to water in some upgradient wells was more than 65 ft below land surface (fig. 4). Depth to water in the vicinity of Hat Rock was about 46 to 56 ft, and depth to water near Oljato Wash was only about 10 ft. The water table in the alluvial aquifer intersects land surface at Oljato Spring (fig. 4) and is shallow enough to be accessed by hand pumps (well 08GS-12-11) in this area.

Water-level contours indicate that ground-water movement in the alluvial aquifer is generally from southeast to northwest, from areas in Mystery Valley to Oljato Wash (fig. 4). The largest volume of ground water probably moves within paleochannel(s) that are present in at least parts of the study area (fig. 5). Discharge to Oljato Wash is mostly subsurface (underflow) because surface-water flow in the

Recharge and Discharge

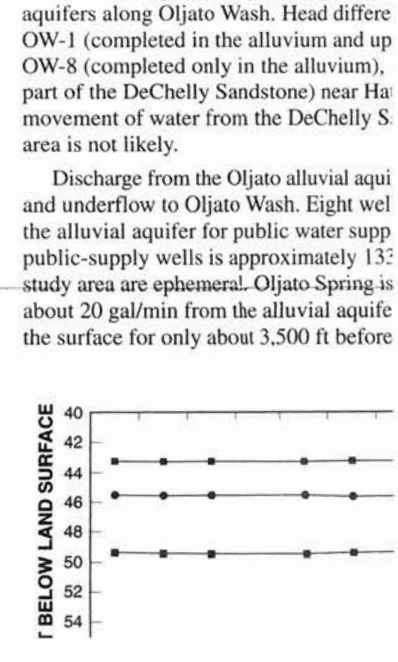
The Oljato alluvial aquifer appears tc valley to Oljato Wash, although the boun are less defined in the Mystery Valley ar primarily from direct precipitation on th infiltrating streamflow that originates as to the valley (fig. 4). Potential ground-w aquifers by upward or lateral movement

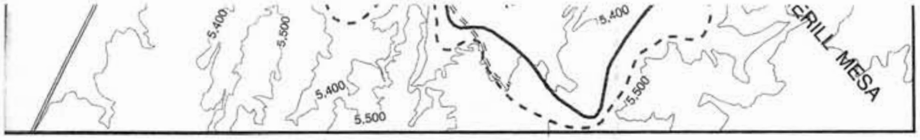
Deposits of dune sand are widesprea to infiltrate rapidly with minimal runoff. over an extensive area, the annual rate o rates can be high. During the summer, pre can evaporate directly through capillary subsequently transpired. During the wint are substantially lower, infiltrating moist evapotranspiration takes place. Thus, the alluvial aquifer is during the winter (Coc

Runoff from precipitation on adjacen particularly during and after summer thu the sandy alluvium along or within a sho runoff occurs in canyons that have devel margins. Infiltration takes place where th canyons and flow into the valley. Areas of from adjacent mesas and canyons are sh

Deeper regional aquifers underlie the source of recharge to the alluvial aquifer immediately west of Oljato has brought c particularly the Permian-age Cedar Mesa by infiltrating precipitation. However, m from this unit would necessitate upward n a poorly permeable formation. Flowing w of the study area (fig. 2) indicate that the conditions and potentially could provide aquifers along Oljato Wash. Head differe OW-1 (completed in the alluvium and up OW-8 (completed only in the alluvium), part of the DeChelly Sandstone) near Ha movement of water from the DeChelly S area is not likely.

Discharge from the Oljato alluvial aqui and underflow to Oljato Wash. Eight wel the alluvial aquifer for public water supp public-supply wells is approximately 13 study area are ephemeral. Oljato Spring is about 20 gal/min from the alluvial aquife the surface for only about 3,500 ft before





Recharge and Discharge

The Oljato alluvial aquifer appears to be largely contained within the tributary valley to Oljato Wash, although the boundaries of the valley, and hence, the aquifer, are less defined in the Mystery Valley area. Thus, recharge to the aquifer originates primarily from direct precipitation on the alluvial deposits in the valley and from infiltrating streamflow that originates as runoff from mesas immediately adjacent to the valley (fig. 4). Potential ground-water inflow from deeper consolidated-rock aquifers by upward or lateral movement also might take place in some areas.

Deposits of dune sand are widespread in the study area and precipitation tends to infiltrate rapidly with minimal runoff. Although recharge from precipitation occurs over an extensive area, the annual rate of recharge is probably low and evaporation rates can be high. During the summer, precipitation that infiltrates the surface deposits can evaporate directly through capillary motion or be absorbed by vegetation and subsequently transpired. During the winter, when temperatures and evaporation rates are substantially lower, infiltrating moisture can penetrate below the zone where evapotranspiration takes place. Thus, the greatest potential for areal recharge to the alluvial aquifer is during the winter (Cooley and others, 1969).

Runoff from precipitation on adjacent mesas also recharges the alluvial aquifer, particularly during and after summer thunderstorms. Runoff from mesas infiltrates the sandy alluvium along or within a short distance of cliff margins. In addition, runoff occurs in canyons that have developed by headward erosion into the cliff margins. Infiltration takes place where these ephemeral streams emerge from the canyons and flow into the valley. Areas of potential contribution to the alluvial aquifer from adjacent mesas and canyons are shown in figure 4.

Deeper regional aquifers underlie the study area and possibly could provide a source of recharge to the alluvial aquifer in some areas. Structural upwarping immediately west of Oljato has brought consolidated-rock formations to the surface, particularly the Permian-age Cedar Mesa Sandstone, where they can be recharged by infiltrating precipitation. However, movement of water into the alluvial aquifer from this unit would necessitate upward movement through the Organ Rock Tongue, a poorly permeable formation. Flowing wells in the El Capitan Wash area southwest of the study area (fig. 2) indicate that the DeChelly Sandstone is under artesian conditions and potentially could provide an upward source of water to alluvial aquifers along Oljato Wash. Head differences of less than 0.2 ft between wells OW-1 (completed in the alluvium and upper part of the DeChelly Sandstone), OW-8 (completed only in the alluvium), and OW-9 (completed only in the upper part of the DeChelly Sandstone) near Hat Rock, however, suggest that upward movement of water from the DeChelly Sandstone into the alluvial aquifer in this area is not likely.

Discharge from the Oljato alluvial aquifer is from ground-water pumpage, springs, and underflow to Oljato Wash. Eight wells in the study area withdraw water from the alluvial aquifer for public water supply (table 3). Average total discharge from public-supply wells is approximately 133 acre-ft/yr (table 3). Most springs in the study area are ephemeral. Oljato Spring is the largest perennial spring and discharges about 20 gal/min from the alluvial aquifer; however, water from the spring flows on the surface for only about 3,500 ft before infiltrating back into the alluvium (fig. 4).

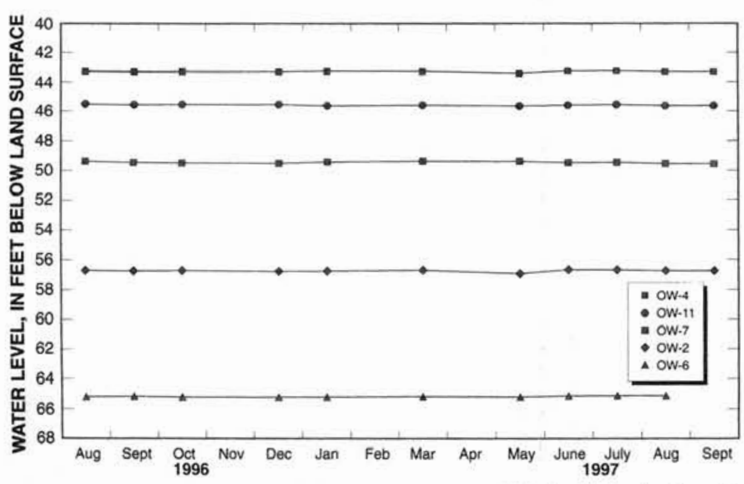


Figure 6. Monthly water-level measurements for selected wells in the Oljato alluvial aquifer, Monument Valley area, Utah and Arizona.

conductance were measured in the
from public-supply wells were co
at least 2 hours. Water-quality sam
the study were collected after well
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Quality Laboratory in Arvada, Co

Specific conductance (field) of water
from 330 to 1,290 µS/cm at 25°C; howev
contained water with a specific conductance
dissolved-solids (residue) concentration i
to 789 mg/L, and water from most wells
Water with dissolved-solids concentratio
"fresh" (Heath, 1989, table 2, p. 65). Wat
08A-216B in the community of Oljato co
concentrations in the study area (table 4)
ranged from 14.0 to 17.0°C. The pH (fiel
from 7.8 to 8.2.

Hardness in water from wells ranged
mg/L; hardness in most water was betwe
to the classification of Durfor and Becker
aquifer would be considered "hard."

Results of chemical analyses indicate
aquifer is a calcium-magnesium-bicarbo
community of Oljato, well 08T-554, and
magnesium-bicarbonate-sulfate type. Hig
from the Oljato area are attributed to inc
(table 4).

Differences in water chemistry gener
ground-water flow paths and (or) mixin
compositions. Some wells in the study
underlying bedrock units, which allows
compositions to mix. Increased concentr
in downgradient areas might have result
or formations rather than from chemica
path. The driller's record for well 08A-
water from the alluvium (land surface t
conductance of water from the underlyi
µS/cm. This implies that high sodium a
alluvium do not result from mixing with
Because water in the alluvium near Olj
aquifer is particularly susceptible to the
in the area that contain poorer quality wa
Formations, and to potential effects of
in downgradient areas possibly could be
bedrock, although potential well yields

SUMMARY

Water supply for residents of the Mo
this, the Navajo Nation Department of W
Geological Survey, investigated the hyd
aquifer along a tributary of Oljato Wash,
is contained within unconsolidated dep
Member and Organ Rock Tongue of the
thickness of the aquifer is 101 ft near H
and upgradient from this area. Thickest
paleochannel(s). Areal extent of the allu

Transmissivity values reported and de
alluvial aquifer range from less than 100
a U.S. Geological Survey aquifer test, po
130 gal/min. Specific capacity ranges fro
larger values generally correspond with a

Water-level contours indicate that gro
aquifer is generally from southeast to no
Oljato Wash. Monthly measurements of w
1997 varied only 0.2 ft or less. Depth to
downgradient as land-surface altitude also
from about 65 ft below land surface in up

Table 4. Physical properties and major chemic
[°C, degrees Celsius; µS/cm, microsiemens per cen
Map number: Refer to numbering system for hydrol

Specific con- Specific con- p

about 20 percent for sand and gravel (Heath, 1989, p. 9), a volume of about 57,000 acre-ft potentially would be available for withdrawal from the aquifer. At an annual recharge rate of 300 acre-ft, as previously calculated, about 200 years would be required to replenish this loss from storage.

CHEMICAL QUALITY OF GROUND WATER

Water samples from 18 wells and 1 spring were collected during this study and analyzed for major ions, selected trace metals, alkalinity, and dissolved-solids concentration to assess variations in water quality in the Oljato alluvial aquifer (table 4). Water-quality data for three additional sites (wells 08A-216, 08A-216A, and 08-0613) also are reported. Temperature, pH, and specific conductance were measured in the field at most sites. Water-quality samples from public-supply wells were collected after wells had been pumping for at least 2 hours. Water-quality samples from monitoring wells drilled during the study were collected after wells had been developed for 1 to 2 hours. All water samples were analyzed by the U.S. Geological Survey National Water Quality Laboratory in Arvada, Colorado.

Specific conductance (field) of water from wells in the alluvial aquifer ranged from 330 to 1,290 µS/cm at 25°C; however, all but five wells and Oljato Spring contained water with a specific conductance less than 500 µS/cm (table 4). Concurrently, dissolved-solids (residue) concentration in water from the aquifer ranged from 179 to 789 mg/L, and water from most wells contained less than 300 mg/L (table 4). Water with dissolved-solids concentrations less than 1,000 mg/L is classified as "fresh" (Heath, 1989, table 2, p. 65). Water from wells 08A-216, 08A-216A, and 08A-216B in the community of Oljato contained the highest dissolved-solids concentrations in the study area (table 4). Temperature of water from most wells ranged from 14.0 to 17.0°C. The pH (field) of water from wells generally ranged from 7.8 to 8.2.

Hardness in water from wells ranged from 84 mg/L as $CaCO_3$ to as much as 452 mg/L; hardness in most water was between 120 and 180 mg/L (table 4). According to the classification of Durfor and Becker (1964, p. 27), most water from the alluvial aquifer would be considered "hard."

Results of chemical analyses indicate that water from most wells in the alluvial aquifer is a calcium-magnesium-bicarbonate type (fig. 7). Water from wells in the community of Oljato, well 08T-554, and from Oljato Spring, however, is a sodium-magnesium-bicarbonate-sulfate type. Higher dissolved-solids concentrations in water from the Oljato area are attributed to increased concentrations of sodium and sulfate (table 4).

Differences in water chemistry generally result from chemical interactions along ground-water flow paths and (or) mixing of waters with different chemical compositions. Some wells in the study area are open to both the alluvium and the underlying bedrock units, which allows water of potentially different chemical compositions to mix. Increased concentrations of sodium and sulfate in ground water in downgradient areas might have resulted from mixing with water from other areas or formations rather than from chemical interactions along the ground-water flow path. The driller's record for well 08A-216B indicates that specific conductance of water from the alluvium (land surface to 30 ft) was 1,230 µS/cm, and specific conductance of water from the underlying DeChelly Sandstone (30 to 50 ft) was 450 µS/cm. This implies that high sodium and sulfate concentrations in water from the alluvium do not result from mixing with water in the underlying bedrock in this area. Because water in the alluvium near Oljato Wash is within 15 ft of land surface, the aquifer is particularly susceptible to the effects of inflow from other bedrock units in the area that contain poorer quality water, particularly the Shinarump and Moenkopi Formations, and to potential effects of human activities. Thus, better quality water in downgradient areas possibly could be obtained by well completion in the underlying bedrock, although potential well yields generally are low.

SUMMARY

Water supply for residents of the Monument Valley area is limited. Because of this, the Navajo Nation Department of Water Resources, in cooperation with the U.S. Geological Survey, investigated the hydrology of, and quality of water in, an alluvial aquifer along a tributary of Oljato Wash, near Oljato, Utah. The Oljato alluvial aquifer is contained within unconsolidated deposits that overlie the DeChelly Sandstone Member and Organ Rock Tongue of the Permian-age Cutler Formation. Maximum thickness of the aquifer is 101 ft near Hat Rock and decreases both downgradient and upgradient from this area. Thickest alluvium probably is associated with paleochannel(s). Areal extent of the alluvial aquifer is about 9,500 acres.

Transmissivity values reported and determined for selected wells in the Oljato alluvial aquifer range from less than 100 to as much as 2,800 ft²/d. On the basis of a U.S. Geological Survey aquifer test, potential well yield in some areas is at least 130 gal/min. Specific capacity ranges from 0.6 to 5.8 (gal/min)/ft of drawdown, and larger values generally correspond with areas of high transmissivity.

Water-level contours indicate that ground-water movement in the Oljato alluvial aquifer is generally from southeast to northwest, from areas in Mystery Valley to

County, Utah: U.S. Geological Survey Bulletir

Cooley, M.E., Akers, J.P., and Stevens, P. R., 1964, (Hopi Indian Reservations, Arizona, New Mexic logs, drillers' logs, and stratigraphic sections: . Resources Report Number Twelve-C, 157 p.

Cooley, M.E., and others, 1966, Geohydrologic data in Arizona, New Mexico, and Utah; Part III—M and stratigraphic sections: Arizona State Land Number Twelve-D, 2 sheets.

Cooley, M.E., Harshbarger, J.W., Akers, J.P., and Ha of the Navajo and Hopi Indian Reservations, / section on Vegetation, by O.N. Hicks: U.S. Ge A, 61 p.

Davis, G.E., Hardt, W.F., Thompson, L.K., and Coc the Navajo and Hopi Indian Reservations, Ari Records of Ground-Water Supplies: Arizona ! Report Number Twelve-A, 159 p.

Durfor, C.N., and Becker, Edith, 1964, Public wate United States, 1962: U.S. Geological Survey

Heath, R.C., 1989, Basic ground-water hydrology: Paper 2220, 84 p.

Irwin, J.H., Stevens, P.R., and Cooley, M.E., 1971, and Hopi Indian Reservations, Arizona, New M Professional Paper 521-C, 32 p.

Jacob, C.E., 1963, Determining the permeability o compiler, Methods of determining permeabil Geological Survey Water-Supply Paper 1536

Kister, L.R., and Hatchett, J.L., 1963, Geohydrolo Reservations, Arizona, New Mexico, and Ut of the ground water: Arizona State Land Dep Twelve-B, 58 p.

Longsworth, S.A., 1994, Geohydrology and water and radiochemistry of spoil-material leachat Arizona and Utah: U.S. Geological Survey W 4226, 43 p.

McDonald, J.E., 1956, Variability of precipitation in for Arizona: Arizona University Institute of / Meteorology and Climatology, Arid Regions

McGavock, E.H., Edmonds, R.J., Gillespie, E.L., data in the Navajo and Hopi Indian Reservati I-A—Supplemental Records of Ground-Wate Water-Resources Report Number Twelve-E,

Naftz, D.L., and Spangler, L.E., 1994, Salinity incr Utah: Water Resources Bulletin, v. 30, no. 6

Neuman, S.P., 1974, Effect of partial penetration o delayed gravity response: Water Resources I

U.S. Bureau of Reclamation, 1986, Procedure for (visual method): U.S. Bureau of Reclamatio

CONVERSION FACTORS, VI ABBREVIATED WATER

Multiply	By
inch (in.)	0.02
inch per year (in/yr)	0.02
mile (mi)	1.60
square mile (mi²)	2.59
foot (ft)	0.30
square foot (ft²)	0.09
foot per day (ft/d)	0.30
foot squared per day (ft²/d)[1]	0.09
foot per mile (ft/mi)	0.18
gallon (gal)	3.7
gallon per minute (gal/min)	0.06
gallon per minute per foot [(gal/min)/ft]	0.20
gallon per month (gal/month)	3.7
acre	0.40
acre-foot (acre-ft)	0.001
acre-foot per year (acre-ft/yr)	0.001

[1]The standard unit for transmissivity is cubic foot p [(ft³/d)/ft²]ft. In this report, the mathematically reduce convenience.

In this report, degrees are reported in Celsius (°C), (°F) by the following equation:

°F = 9/5(°C)+

Sea level: In this report, "sea level" refers to the Na of 1929)—a geodetic datum derived from a general a

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ROUND WATER

l 1 spring were collected during this study
:d trace metals, alkalinity, and dissolved-
ions in water quality in the Oljato alluvial
for three additional sites (wells 08A-216,
eported. Temperature, pH, and specific
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: U.S. Geological Survey National Water
rado.

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120 and 180 mg/L (table 4). According
964, p. 27), most water from the alluvial

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e type (fig. 7). Water from wells in the
m Oljato Spring, however, is a sodium-
dissolved-solids concentrations in water
ed concentrations of sodium and sulfate

result from chemical interactions along
waters with different chemical
are open to both the alluvium and the
er of potentially different chemical
is of sodium and sulfate in ground water
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ractions along the ground-water flow
indicates that specific conductance of
ft) was 1,230 µS/cm, and specific
Chelly Sandstone (30 to 50 ft) was 450
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Resources, in cooperation with the U.S.
of, and quality of water in, an alluvial
Oljato, Utah. The Oljato alluvial aquifer
hat overlie the DeChelly Sandstone
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ium probably is associated with
aquifer is about 9,500 acres.

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creases. Measured depth to water ranged

..., 1964, Geohydrologic data in the Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah; Part III—Selected lithologic logs, drillers' logs, and stratigraphic sections: Arizona State Land Department Water-Resources Report Number Twelve-C, 157 p.

Cooley, M.E., and others, 1966, Geohydrologic data in the Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah; Part III—Maps showing locations of wells, springs, and stratigraphic sections: Arizona State Land Department Water-Resources Report Number Twelve-D, 2 sheets.

Cooley, M.E., Harshbarger, J.W., Akers, J.P., and Hardt, W.R., 1969, Regional hydrogeology of the Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah, with a section on Vegetation, by O.N. Hicks: U.S. Geological Survey Professional Paper 521-A, 61 p.

Davis, G.E., Hardt, W.F., Thompson, L.K., and Cooley, M.E., 1963, Geohydrologic data in the Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah; Part I—Records of Ground-Water Supplies: Arizona State Land Department Water-Resources Report Number Twelve-A, 159 p.

Durfor, C.N., and Becker, Edith, 1964, Public water supplies of the 100 largest cities in the United States, 1962: U.S. Geological Survey Water-Supply Paper 1812, 364 p.

Heath, R.C., 1989, Basic ground-water hydrology: U.S. Geological Survey Water-Supply Paper 2220, 84 p.

Irwin, J.H., Stevens, P.R., and Cooley, M.E., 1971, Geology of the Paleozoic rocks, Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah: U.S. Geological Survey Professional Paper 521-C, 32 p.

Jacob, C.E., 1963, Determining the permeability of water-table aquifers, *in* Bentall, Ray, compiler, Methods of determining permeability, transmissibility, and drawdown: U.S. Geological Survey Water-Supply Paper 1536-I, p. 245-271.

Kister, L.R., and Hatchett, J.L., 1963, Geohydrologic data in the Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah; Part II—Selected chemical analyses of the ground water: Arizona State Land Department Water-Resources Report Number Twelve-B, 58 p.

Longsworth, S.A., 1994, Geohydrology and water chemistry of abandoned uranium mines and radiochemistry of spoil-material leachate, Monument Valley and Cameron areas, Arizona and Utah: U.S. Geological Survey Water-Resources Investigations Report 93-4226, 43 p.

McDonald, J.E., 1956, Variability of precipitation in an arid region—a survey of characteristics for Arizona: Arizona University Institute of Atmospheric Physics, Technical Report of Meteorology and Climatology, Arid Regions 1, 88 p.

McGavock, E.H., Edmonds, R.J., Gillespie, E.L., and Halpenny, P.C., 1966, Geohydrologic data in the Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah; Part I-A—Supplemental Records of Ground-Water Supplies: Arizona State Land Department Water-Resources Report Number Twelve-E, 55 p.

Naftz, D.L., and Spangler, L.E., 1994, Salinity increases in the Navajo aquifer in southeastern Utah: Water Resources Bulletin, v. 30, no. 6, p. 1119-1135.

Neuman, S.P., 1974, Effect of partial penetration on flow in unconfined aquifers considering delayed gravity response: Water Resources Research, v. 10, no. 2, p. 303-312.

U.S. Bureau of Reclamation, 1986, Procedure for determining unified soil classification (visual method): U.S. Bureau of Reclamation 5005-86, p. 204-215.

CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
inch (in.)	0.0254	meter
inch per year (in/yr)	0.0254	meter per year
mile (mi)	1.609	kilometer
square mile (mi²)	2.590	square kilometer
foot (ft)	0.3048	meter
square foot (ft²)	0.0929	square meter
foot per day (ft/d)	0.3048	meter per day
foot squared per day (ft²/d)[1]	0.0929	square meter per day
foot per mile (ft/mi)	0.1894	meter per kilometer
gallon (gal)	3.785	liter
gallon per minute (gal/min)	0.0631	liter per second
gallon per minute per foot [(gal/min)/ft]	0.2070	liter per second per meter
gallon per month (gal/month)	3.785	liter per month
acre	0.4047	square hectometer
acre-foot (acre-ft)	0.001233	cubic hectometer
acre-foot per year (acre-ft/yr)	0.001233	cubic hectometer per year

[1]The standard unit for transmissivity is cubic foot per day per square foot of aquifer thickness [(ft³/d)/ft²]ft. In this report, the mathematically reduced form, foot squared per day (ft²/d), is used for convenience.

In this report, degrees are reported in Celsius (°C), which can be converted to degrees Fahrenheit (°F) by the following equation:

$$°F = 9/5(°C)+32.$$

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Chemical concentration and water temperature are given only in metric units. Chemical concentration is given in milligrams per liter (mg/L) or micrograms per liter (µg/L). Milligrams per liter is a unit expressing the solute...

In addition, water levels measured in some wells also can be influenced by inflow of water from underlying bedrock units where both the alluvium and bedrock are open to the well and head differences exist between the units.

Monthly measurements of water levels from August 1996 to September 1997 in five wells are shown in figure 6. Water levels in most wells varied only 0.2 ft or less during this period. Daily water-level measurements in well OW-2 for the month prior to an aquifer test in December 1996 also show variations of less than 0.04 ft, even during changes in barometric pressure (U.S. Geological Survey aquifer test, December 11-17, 1996). Water levels measured in some wells during this study were virtually the same as water levels measured when the wells were drilled (table 1). Long-term water-level data for the alluvial aquifer do not exist and would be necessary to document variability caused by seasonal effects and potential water-level declines from pumpage.

Depth to water in the study area generally decreases downgradient as land-surface altitude also decreases. Measured depth to water in some upgradient wells was more than 65 ft below land surface (fig. 4). Depth to water in the vicinity of Hat Rock was about 46 to 56 ft, and depth to water near Oljato Wash was only about 10 ft. The water table in the alluvial aquifer intersects land surface at Oljato Spring (fig. 4) and is shallow enough to be accessed by hand pumps (well 08GS-12-11) in this area.

Water-level contours indicate that ground-water movement in the alluvial aquifer is generally from southeast to northwest, from areas in Mystery Valley to Oljato Wash (fig. 4). The largest volume of ground water probably moves within paleochannel(s) that are present in at least parts of the study area (fig. 5). Discharge to Oljato Wash is mostly subsurface (underflow) because surface-water flow in the wash near Oljato is ephemeral. Altitude of the water table on September 23, 1997, in well OW-15 was about 82 ft higher than that in well OW-7, indicating a hydraulic gradient of about 26 ft/mi (0.005) between these wells (fig. 4). In downgradient areas near Oljato Wash, the gradient tends to be steeper because the canyon is substantially narrower than it is in upgradient areas and the aquifer is not as laterally extensive. Altitude of the water table in well 08T-554 was also about 82 ft higher than that in well 08A-216B; however, the hydraulic gradient between these wells is about 62 ft/mi (0.012) (fig. 4). Hydraulic gradients near water-supply wells also are steeper because of the cone of depression formed around pumping wells. Because well spacing in the study area is typically greater than 3,000 ft and public-supply wells are pumped intermittently at rates that are no greater than 85 gal/min, effects of pumpage on neighboring wells probably do not occur.

aquifers along Oljato Wash. Head differ
OW-1 (completed in the alluvium and u
OW-8 (completed only in the alluvium)
part of the DeChelly Sandstone) near H
movement of water from the DeChelly
area is not likely.

Discharge from the Oljato alluvial aqu
and underflow to Oljato Wash. Eight w
the alluvial aquifer for public water sup
public-supply wells is approximately 1
study area are ephemeral. Oljato Spring
about 20 gal/min from the alluvial aquil
the surface for only about 3,500 ft befo

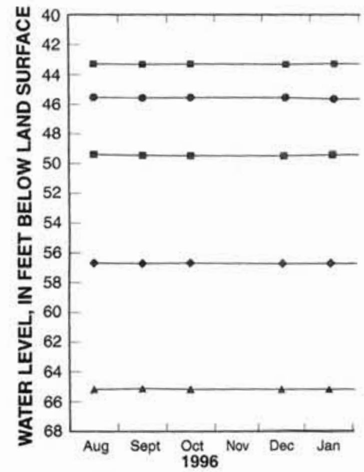

Figure 6. Monthly water-level measuremen
Monument Valley area, Utah and Arizona.

Table 2. Hydraulic properties reported and determined from aquifer testing and specific capacity for selected wells in the Oljato alluvial aquifer
[gal/min, gallons per minute; min, minutes; ft²/d, feet squared per day; ft/d, feet per day; NA, data not available or not applicable]

Pumping and observation wells: Refer to numbering system for hydrologic-data sites; locations shown in figure 2.
Duration: PUM, pumping time; REC, recovery time.
Drawdown: PW, pumping well; OW, observation well.
Specific capacity: (gal/min)/ft, gallons per minute per foot of drawdown.
Transmissivity (reported): values of transmissivity reported by Navajo Nation Department of Water Resources; D, determined from drawdown data; R, detern
Transmissivity (estimated from specific capacity): range in values based on storage coefficients of 0.0004 and 0.0047 determined by Neuman (1974) and Jac
generally overestimate transmissivity where delayed yield effects (gravity drainage) occur.
Transmissivity (calculated): values determined by U.S. Geological Survey.
Remarks: T, transmissivity.

Pumping well	Observation well (distance from pumping well, in feet)	Test date	Pumping rate (gal/min)	Duration (PUM) (min)	Duration (REC) (min)	Drawdown (PW) (feet)	Drawdown (OW) (feet)	Specific capacity [(gal/min)/ft]	Transmissivity (reported) (ft²/d)	Transmissivity (estimated from specific capacity)(ft²/d)	Transmissivity (calculated (ft²/d)
08A-216B	NA	10-15-81	23	1,440	60	4.0	NA	5.8	NA	1,300-1,500	NA
08T-546	08T-530 (50)	03-01-78	10-43	1,440	30	6.0	0.5	4.5	NA	960-1,100	NA
08T-554	NA (25)	09-01-83	40	1,440	60	28.3	5.3	1.4	290D 310R	260-320	NA
08-0613	NA	08-16-92	31	1,350	NA	17.6	NA	1.8	NA	340-410	NA
08-0614	08-0614-OW (200)	03-02-78	15	4,000	400	25.5	2.32	.6	190	120	NA
08-0615	NA	05-12-78	40	1,350	100	9.0	NA	4.4	2,100D 2,800R	940-1,100	NA
OW-4	NA	12-12-96	10.9	48	55	4.57	NA	2.4	NA	370-470	NA
OW-7	NA	12-11-96	10.9	60	60	5.13	NA	2.1	NA	330-420	NA
OW-8	OW-1 (50) OW-9 (50) OW-10 (100) OW-11 (300)	12-11-96	130	4,320	4,320	23	11.47 7.19 7.87 3.47	5.6	NA	1,600	1,300D 1,200R
OW-14	NA	09-24-97	10.3	25	25	18.8	NA	.6	NA	70-100	NA

Hydrology and water qualit

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conditions and potentially could provide an upward source of water to alluvial aquifers along Oljato Wash. Head differences of less than 0.2 ft between wells OW-1 (completed in the alluvium and upper part of the DeChelly Sandstone), OW-8 (completed only in the alluvium), and OW-9 (completed only in the upper part of the DeChelly Sandstone) near Hat Rock, however, suggest that upward movement of water from the DeChelly Sandstone into the alluvial aquifer in this area is not likely.

Discharge from the Oljato alluvial aquifer is from ground-water pumpage, springs, and underflow to Oljato Wash. Eight wells in the study area withdraw water from the alluvial aquifer for public water supply (table 3). Average total discharge from public-supply wells is approximately 133 acre-ft/yr (table 3). Most springs in the study area are ephemeral. Oljato Spring is the largest perennial spring and discharges about 20 gal/min from the alluvial aquifer; however, water from the spring flows on the surface for only about 3,500 ft before infiltrating back into the alluvium (fig. 4).

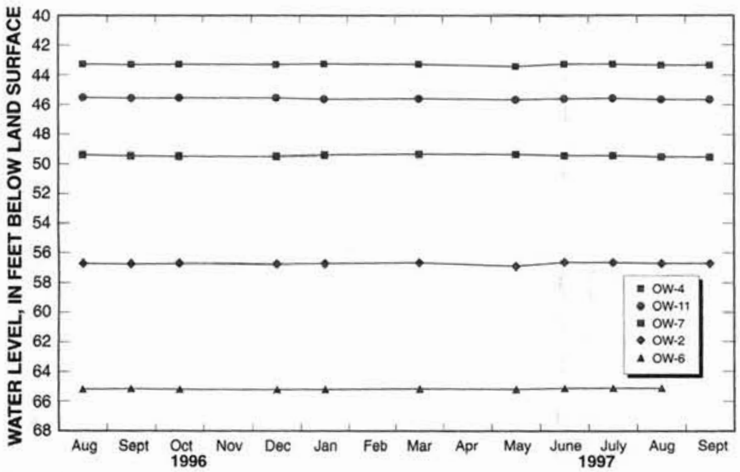

Figure 6. Monthly water-level measurements for selected wells in the Oljato alluvial aquifer, Monument Valley area, Utah and Arizona.

ty for selected wells in the Oljato alluvial aquifer, Monument Valley area, Utah and Arizona
ailable or not applicable]

figure 2.

urces; D, determined from drawdown data; R, determined from recovery data.
4 and 0.0047 determined by Neuman (1974) and Jacob (1963) methods, respectively; calculated values

pecific apacity al/min)/ft]	Trans-missivity (reported) (ft^2/d)	Trans-missivity (estimated from specific capacity)(ft^2/d)	Trans-missivity (calculated) (ft^2/d)	Hydraulic conduc-tivity (ft/d)	Storage coefficient (dimen-sionless)	Remarks
5.8	NA	1,300-1,500	NA	NA	NA	Single-well test
4.5	NA	960-1,100	NA	NA	NA	Step-drawdown test
1.4	290D 310R	260-320	NA	7.3	NA	T determined by Neuman method
1.8	NA	340-410	NA	NA	NA	Single-well test
.6	190	120	NA	3.2	$4.7x10^{-3}$	T determined by Jacob method
4.4	2,100D 2,800R	940-1,100	NA	40	NA	T determined by Jacob method
2.4	NA	370-470	NA	NA	NA	Single-well test
2.1	NA	330-420	NA	NA	NA	Single-well test
5.6	NA	1,600	1,300D 1,200R	13.4	$4.0x10^{-4}$	T determined by Neuman method
.6	NA	70-100	NA	NA	NA	Single-well test

aquifer is particularly susceptible to the eff
in the area that contain poorer quality water,
Formations, and to potential effects of hum
in downgradient areas possibly could be obta
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SUMMARY

Water supply for residents of the Monu
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larger values generally correspond with are

Water-level contours indicate that grour
aquifer is generally from southeast to nortl
Oljato Wash. Monthly measurements of wa
1997 varied only 0.2 ft or less. Depth to wa
downgradient as land-surface altitude also d
from about 65 ft below land surface in upg

Table 4. Physical properties and major chemical
[°C, degrees Celsius; μS/cm, microsiemens per centi
Map number: Refer to numbering system for hydrolo

Map number	Date sampled	Water tempera-ture (°C)	Specific con-duct-ance, field (μS/cm)	Specific con-duct-ance, lab (μS/cm)	pH fiel (sta an unit
OW-1	07-18-96	20	345	354	8.7
OW-2	12-14-96	14	330	328	8.C
	07-18-96	20	445	423	8.7
OW-3	07-19-96	—	—	826	—
OW-4	07-20-96	17	420	408	8.
OW-6	07-22-96	19	475	484	—
OW-7	07-25-96	17	420	385	8.
OW-8	12-14-96	14.5	350	361	8.
	07-24-96	16	375	359	8.
OW-14	08-27-97	17.5	410	401	8.
OW-15	08-28-97	17	385	373	8.
08A-216	10-01-48	—	1,230	—	—
08A-216A	09-30-54	15	989	—	—
08A-216B	01-27-97	15	1,290	1,270	7.
	09-30-54	20	986	—	—
[7]08A-217	01-28-97	8.0	860	846	8.
	06-08-48	—	997	—	—
08K-402	01-25-97	13	480	481	8.
	08-11-49	15.5	913	—	—
08K-417	01-28-97	15	400	386	8.
	11-10-48	—	392	—	—
08P-451	01-23-97	15	365	368	8
08T-546	12-18-96	15	335	328	8
08T-554	01-27-97	16	710	701	7
08-0613	[5]06-12-96	—	—	407	—
08-0614	12-16-96	14	530	525	8
08-0615	12-16-96	14	330	338	8
08-0651	12-15-96	16	365	362	8

[1] Alkalinity determined from bicarbonate concentration.
[2] Alkalinity (field), 210 mg/L as $CaCO_3$; bicarbonate, 25
[3] Alkalinity reported as field value; bicarbonate, 212 mg
[4] Alkalinity reported as field value; bicarbonate, 216 mg
[5] Analysis by Inter-Mountain Laboratories, Farmington,
[6] Sodium plus potassium.
[7] 08A-217, Spring discharges from numerous seeps alc

gy and water quality of the Oljato alluvial aquifer, Monument

By

L.E. Spangler, U.S. Geological Survey; and M.S. Johnson, Navajo Nation Department of Wa

1999

ecause water in the alluvium near Oljato Wash is within 15 ft of land surface, the quifer is particularly susceptible to the effects of inflow from other bedrock units n the area that contain poorer quality water, particularly the Shinarump and Moenkopi ormations, and to potential effects of human activities. Thus, better quality water n downgradient areas possibly could be obtained by well completion in the underlying edrock, although potential well yields generally are low.

UMMARY

Water supply for residents of the Monument Valley area is limited. Because of s, the Navajo Nation Department of Water Resources, in cooperation with the U.S. ological Survey, investigated the hydrology of, and quality of water in, an alluvial uifer along a tributary of Oljato Wash, near Oljato, Utah. The Oljato alluvial aquifer contained within unconsolidated deposits that overlie the DeChelly Sandstone mber and Organ Rock Tongue of the Permian-age Cutler Formation. Maximum ckness of the aquifer is 101 ft near Hat Rock and decreases both downgradient upgradient from this area. Thickest alluvium probably is associated with ochannel(s). Areal extent of the alluvial aquifer is about 9,500 acres.

Transmissivity values reported and determined for selected wells in the Oljato vial aquifer range from less than 100 to as much as 2,800 ft^2/d. On the basis of S. Geological Survey aquifer test, potential well yield in some areas is at least gal/min. Specific capacity ranges from 0.6 to 5.8 (gal/min)/ft of drawdown, and er values generally correspond with areas of high transmissivity.

Water-level contours indicate that ground-water movement in the Oljato alluvial fer is generally from southeast to northwest, from areas in Mystery Valley to to Wash. Monthly measurements of water levels from August 1996 to September 7 varied only 0.2 ft or less. Depth to water in the study area generally decreases ngradient as land-surface altitude also decreases. Measured depth to water ranged about 65 ft below land surface in upgradient areas to only about 10 ft near

CONVERSION FACTORS, VER
ABBREVIATED WATER-Q

Multiply	By
inch (in.)	0.0254
inch per year (in/yr)	0.0254
mile (mi)	1.609
square mile (mi^2)	2.590
foot (ft)	0.3048
square foot (ft^2)	0.0929
foot per day (ft/d)	0.3048
foot squared per day (ft^2/d)[1]	0.0929
foot per mile (ft/mi)	0.1894
gallon (gal)	3.785
gallon per minute (gal/min)	0.0631
gallon per minute per foot [(gal/min)/ft]	0.2070
gallon per month (gal/month)	3.785
acre	0.4047
acre-foot (acre-ft)	0.001233
acre-foot per year (acre-ft/yr)	0.001233

[1]The standard unit for transmissivity is cubic foot per day $[(ft^3/d)/ft^2]$ft. In this report, the mathematically reduced forr convenience.

In this report, degrees are reported in Celsius (°C), which (°F) by the following equation:

$$°F = 9/5(°C)+32.$$

Sea level: In this report, "sea level" refers to the National (of 1929)—a geodetic datum derived from a general adjustme United States and Canada, formerly called Sea Level Datum

Chemical concentration and water temperature are given onl is given in milligrams per liter (mg/L) or micrograms per lite expressing the solute per unit volume (liter) of water. One th to 1 milligram per liter. For concentrations less than 7,000 mi about the same as for concentrations in parts per million. Speci per centimeter (µS/cm) at 25 degrees Celsius.

4. Physical properties and major chemical constituents in ground-water samples collected from selected wells and a spring in the Oljato alluvial aquifer, Mc egrees Celsius; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; —, no data; <, less than stated value] umber: Refer to numbering system for hydrologic-data sites; locations shown in figure 2.

er	Date sampled	Water temperature (°C)	Specific conductance, field (µS/cm)	Specific conductance, lab (µS/cm)	pH, field (standard units)	pH, lab (standard units)	Hardness, total (mg/L as $CaCO_3$)	Alkalinity, lab (mg/L as $CaCO_3$)	Solids, sum of constituents, dissolved (mg/L)	Solids, residue at 180°C, dissolved (mg/L)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	B mi di sol (m as
	07-18-96	20	345	354	8.7	8.1	140	153	191	194	20	21	24	2.6	22	6.8	0.3	0.0
	12-14-96	14	330	328	8.0	8.3	84	117	178	—	7.7	16	34	2.4	39	7.7	.3	—
	07-18-96	20	445	423	8.7	8.0	96	149	254	253	17	13	59	2.7	62	9.3	.4	.0
	07-19-96	—	—	826	—	8.1	120	215	495	501	16	20	130	5.3	150	33	.6	.2
	07-20-96	17	420	408	8.3	7.9	170	180	235	263	25	27	25	2.4	26	6.8	.3	.0
	07-22-96	19	475	484	—	7.9	190	147	282	287	28	28	35	3.1	72	17	.4	.2
	07-25-96	17	420	385	8.2	8.0	180	179	223	229	29	26	19	2.5	18	6.4	.3	.0
	12-14-96	14.5	350	361	8.0	8.0	150	168	196	196	26	21	14	2.0	13	6.3	.3	—
	07-24-96	16	375	359	8.2	8.0	150	161	197	190	25	22	16	2.4	15	6.7	.3	.0
4	08-27-97	17.5	410	401	8.2	8.1	140	161	223	240	30	16	31	1.7	27	7.8	.3	—
5	08-28-97	17	385	373	8.2	8.2	120	158	210	224	27	12	35	1.8	22	5.9	.2	—
16	10-01-48	—	1,230	—	—	—	452	[1]394	778	—	46	82	[6]124	—	226	61	1.9	—
216A	09-30-54	15	989	—	—	—	304	[1]294	629	—	28	57	[6]116	—	180	50	1.0	—
216B	01-27-97	15	1,290	1,270	7.8	8.0	370	320	783	789	31	72	140	2.1	240	86	.9	—
	09-30-54	20	986	—	—	—	316	[1]307	—	—	31	58	—	—	—	46	1.0	—
217	01-28-97	8.0	860	846	8.2	8.1	300	[2]217	521	525	41	49	70	1.1	160	56	.6	—
	06-08-48	—	997	—	—	—	450	[1]230	659	—	50	79	[6]56	—	299	20	.7	—
402	01-25-97	13	480	481	8.1	8.1	180	173	263	282	34	23	33	1.9	40	13	.3	—
	08-11-49	15.5	913	—	—	—	300	[3]174	598	—	59	37	[6]88	—	230	42	.3	—
17	01-28-97	15	400	386	8.0	8.0	170	179	216	207	24	26	16	2.4	18	7.9	.3	—
	11-10-48	—	392	—	—	—	168	[4]190	213	—	23	27	[6]23	—	19	6.0	.4	—
51	01-23-97	15	365	368	8.0	8.0	160	168	204	198	28	22	14	2.2	15	9.2	.3	—
46	12-18-96	15	335	328	8.0	7.8	150	159	175	179	30	18	6.6	2.0	8.2	3.0	.2	—
54	01-27-97	16	710	701	7.8	7.9	250	244	423	417	40	36	59	2.9	92	33	.4	—
13	[5]06-12-96	—	—	407	—	7.4	190	285	—	230	31	28	20	2.7	32	6.5	.3	—
14	12-16-96	14	530	525	8.0	8.0	220	158	293	312	40	29	20	2.3	68	25	.2	—
15	12-16-96	14	330	338	8.0	8.0	160	158	180	184	31	19	6.8	2.0	9.5	4.5	.2	—
31	12-15-96	16	365	362	8.0	8.1	150	173	198	197	25	22	14	2.2	13	5.6	.3	—

inity determined from bicarbonate concentration.

inity (field), 210 mg/L as $CaCO_3$; bicarbonate, 256 mg/L as HCO_3.

inity reported as field value; bicarbonate, 212 mg/L as HCO_3.

inity reported as field value; bicarbonate, 216 mg/L as HCO_3; carbonate, 6 mg/L as CO_3.

sis by Inter-Mountain Laboratories, Farmington, New Mexico; barium, 0.12 mg/L; selenium, 0.005 mg/L; zinc, 0.12 mg/L.

m plus potassium.

217, Spring discharges from numerous seeps along hillside; source of sample collected in 1948 unknown.

ifer, Monument Valley area, Utah and Arizona

vajo Nation Department of Water Resources

For additional information write to:
District Chief
U.S. Geological Survey
Room 1016, Administration Building
1745 West 1700 South
Salt Lake City, UT 84104

Website http://ut.water.usgs.gov/

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Mystery Valley to
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generally decreases
depth to water ranged
about 10 ft near

CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
inch (in.)	0.0254	meter
inch per year (in/yr)	0.0254	meter per year
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
foot (ft)	0.3048	meter
square foot (ft^2)	0.0929	square meter
foot per day (ft/d)	0.3048	meter per day
foot squared per day (ft^2/d)[1]	0.0929	square meter per day
foot per mile (ft/mi)	0.1894	meter per kilometer
gallon (gal)	3.785	liter
gallon per minute (gal/min)	0.0631	liter per second
gallon per minute per foot [(gal/min)/ft]	0.2070	liter per second per meter
gallon per month (gal/month)	3.785	liter per month
acre	0.4047	square hectometer
acre-foot (acre-ft)	0.001233	cubic hectometer
acre-foot per year (acre-ft/yr)	0.001233	cubic hectometer per year

[1]The standard unit for transmissivity is cubic foot per day per square foot of aquifer thickness $[(ft^3/d)/ft^2]ft$. In this report, the mathematically reduced form, foot squared per day (ft^2/d), is used for convenience.

In this report, degrees are reported in Celsius (°C), which can be converted to degrees Fahrenheit (°F) by the following equation:

$$°F = 9/5(°C)+32.$$

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Chemical concentration and water temperature are given only in metric units. Chemical concentration is given in milligrams per liter (mg/L) or micrograms per liter (µg/L). Milligrams per liter is a unit expressing the solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to 1 milligram per liter. For concentrations less than 7,000 milligrams per liter, the numerical value is about the same as for concentrations in parts per million. Specific conductance is given in microsiemens per centimeter (µS/cm) at 25 degrees Celsius.

ater samples collected from selected wells and a spring in the Oljato alluvial aquifer, Monument Valley area, Utah and Arizona
s; mg/L, milligrams per liter; µg/L, micrograms per liter; —, no data; <, less than stated value]
wn in figure 2.

ka- ty, b L as O3)	Solids, sum of constituents, dissolved (mg/L)	Solids, residue at 180°C, dissolved (mg/L)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Bromide, dissolved (mg/L as Br)	Silica, dissolved (mg/L as SiO_2)	Iron, dissolved (mg/L as Fe)	Manganese, dissolved (mg/L as Mn)	Nitrate, total (mg/L as NO_3)
[illegible]	191	194	20	21	24	2.6	22	6.8	0.3	0.06	2.4	4	30	—
[illegible]	178	—	7.7	16	34	2.4	39	7.7	.3	—	.3	3	1	—
[illegible]	254	253	17	13	59	2.7	62	9.3	.4	.08	1.3	21	46	—
[illegible]	495	501	16	20	130	5.3	150	33	.6	.27	11	3	1	—
[illegible]	235	263	25	27	25	2.4	26	6.8	.3	.08	14	4	52	—
[illegible]	282	287	28	28	35	3.1	72	17	.4	.2	10	27	80	—
[illegible]	223	229	29	26	19	2.5	18	6.4	.3	.08	14	7	29	—
[illegible]	196	196	26	21	14	2.0	13	6.3	.3	—	13	3	1	—
[illegible]	197	190	25	22	16	2.4	15	6.7	.3	.08	13	6	2	—
[illegible]	223	240	30	16	31	1.7	27	7.8	.3	—	12	69	20	—
[illegible]	210	224	27	12	35	1.8	22	5.9	.2	—	12	71	44	—
[illegible]	778	—	46	82	[6]124	—	226	61	1.9	—	—	—	—	.9
[illegible]	629	—	28	57	[6]116	—	180	50	1.0	—	18	—	—	2.9
[illegible]	783	789	31	72	140	2.1	240	86	.9	—	19	3	1	—
[illegible]	—	—	31	58	—	—	—	46	1.0	—	—	—	—	—
[illegible]	521	525	41	49	70	1.1	160	56	.6	—	13	3	1	—
[illegible]	659	—	50	79	[6]56	—	299	20	.7	—	16	—	—	.3
[illegible]	263	282	34	23	33	1.9	40	13	.3	—	14	26	1	—
[illegible]	598	—	59	37	[6]88	—	230	42	.3	—	16	—	—	2.2
[illegible]	216	207	24	26	16	2.4	18	7.9	.3	—	14	4	1	—
[illegible]	213	—	23	27	[6]23	—	19	6.0	.4	—	—	—	—	2.2
[illegible]	204	198	28	22	14	2.2	15	9.2	.3	—	13	3	1	—
[illegible]	175	179	30	18	6.6	2.0	8.2	3.0	.2	—	12	3	1	—
[illegible]	423	417	40	36	59	2.9	92	33	.4	—	13	4	3	—
[illegible]	—	230	31	28	20	2.7	32	6.5	.3	—	—	110	<10	.71
293	312	40	29	20	2.3	68	25	.2	—	14	3	1	—
180	184	31	19	6.8	2.0	9.5	4.5	.2	—	12	3	1	—
198	197	25	22	14	2.2	13	5.6	.3	—	12	3	1	—

0.005 mg/L; zinc, 0.12 mg/L.

48 unknown.

tah and Arizona

For additional information write to:
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